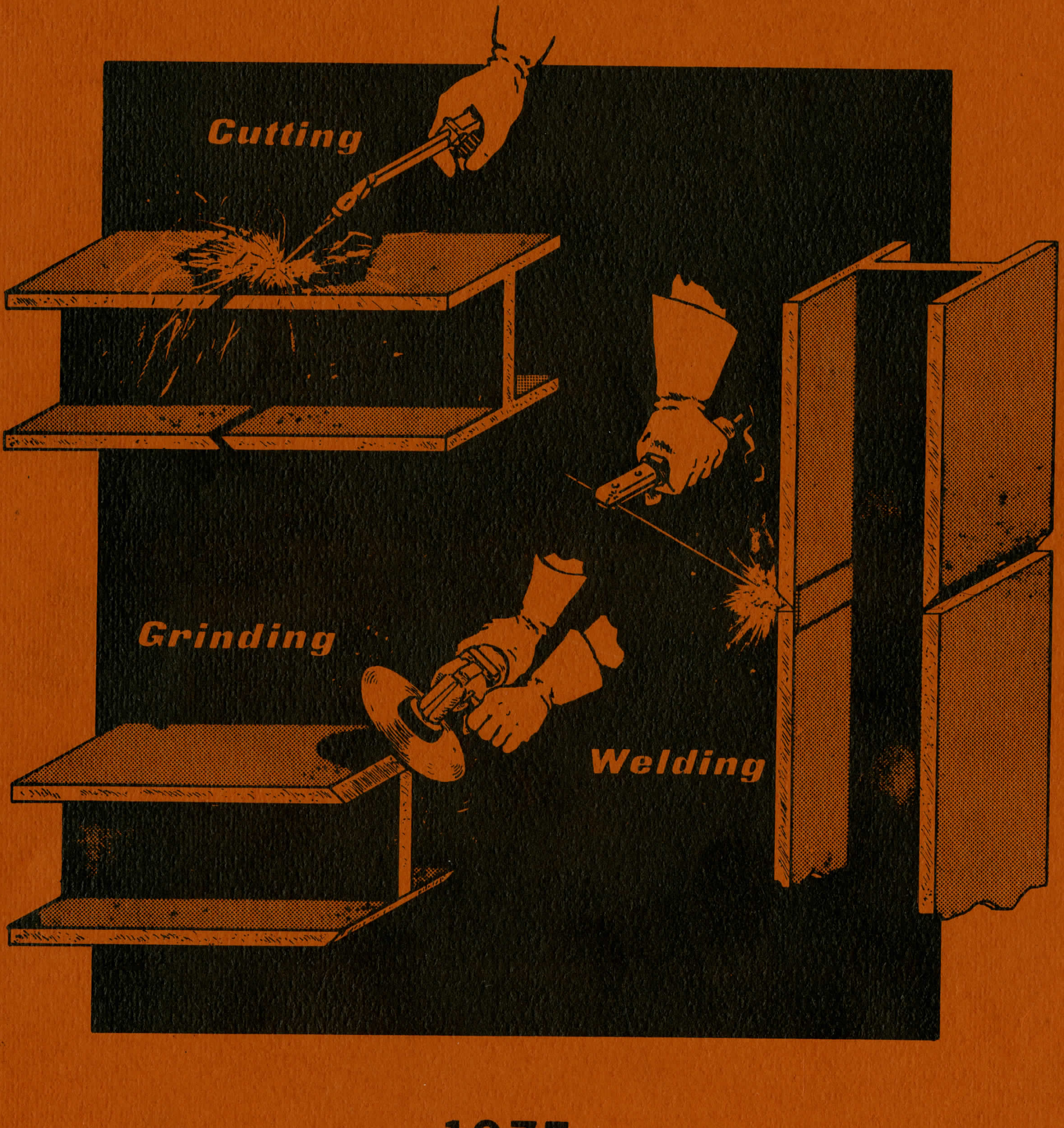
Geology

IOWA STATE HIGHWAY COMMISSION

FIELD WELDING



1975

FIELD WELDING INSPECTION MANUAL

INDEX

PREFACE

This manual is written to help meet a continuing and growing need among Inspectors whose common interest is to function as welding inspectors in addition to their other inspection duties. These inspectors function under the direction of the Resident Construction Engineers. Despite the wide diversity in training and background of these inspectors it becomes more evident each year that continued progress is increasingly more dependent upon technical review of the specifications.

With the increased use of the new higher strength steels it is even more important than ever before that better welding inspectors are needed to understand and to enforce the specifications so that the minimum design criterias are incorporated into the final structure.

Since welding is essentially a metallurgical operation it is best that the inspector understand a few of the basic fundamentals and the technology in applying this knowledge to obtain sound weldments. The illustrated procedures, inspection methods and data presented in this manual are for the inspectors beneficial study and to reinforce his periodic references to various welding problems.

All references to the American Welding Society Specifications are to the AWS D1.1-72 (including revision 1-73) and as modified by the American Association of State Highway and Transportation Officials 1974 Standard Specifications for Welding of Structural Steel Highway Bridges and by the Iowa State Highway Commission's Standard Specifications.

SECTION I

Opportunity and Use

This manual outlines the inspector's duties and responsibilities for the proper anspection of weldments made under field conditions by the shielded metal arc process. It is intended as an informational source for the inspection of methods and weldments.

It is the responsibility of the Engineer or the supervisor appointed by him to see that proper methods outlined in this manual are understood and applied to the respective work.

Most of the welding specifications are incorporated into this manual but the inspector may find particular instances where the plans will carry additional welding requirements, and in those cases the plans must at all times be followed.

There are at times, errors on the plans, especially on the use of welding symbols. Whenever there is reason to question a particular drawing the inspector should consult his Engineer and have him verify it with the Design Department at Ames.

SECTION II

Welding Processes and Terminology

"Welding is a localized coalescence of metal wherein coalescence is produced by heating to suitable temperatures, with or without the application of pressure, and with or without the application of filler metal. The filler metal either has a melting point approximately the same as the base metal or has a melting point below that of the base metal but above 800 F."

Resistance welding is a form of welding that uses pressure but no filler metal. Manual shielded metal arc welding is a form of welding that uses a filler metal that melts at the approximate temperature of the base metal and uses no pressure. Brazing is a form of welding because the filler metal is always above 800 F and that soldering is not a form of welding because its filler metal is always below 800 F.

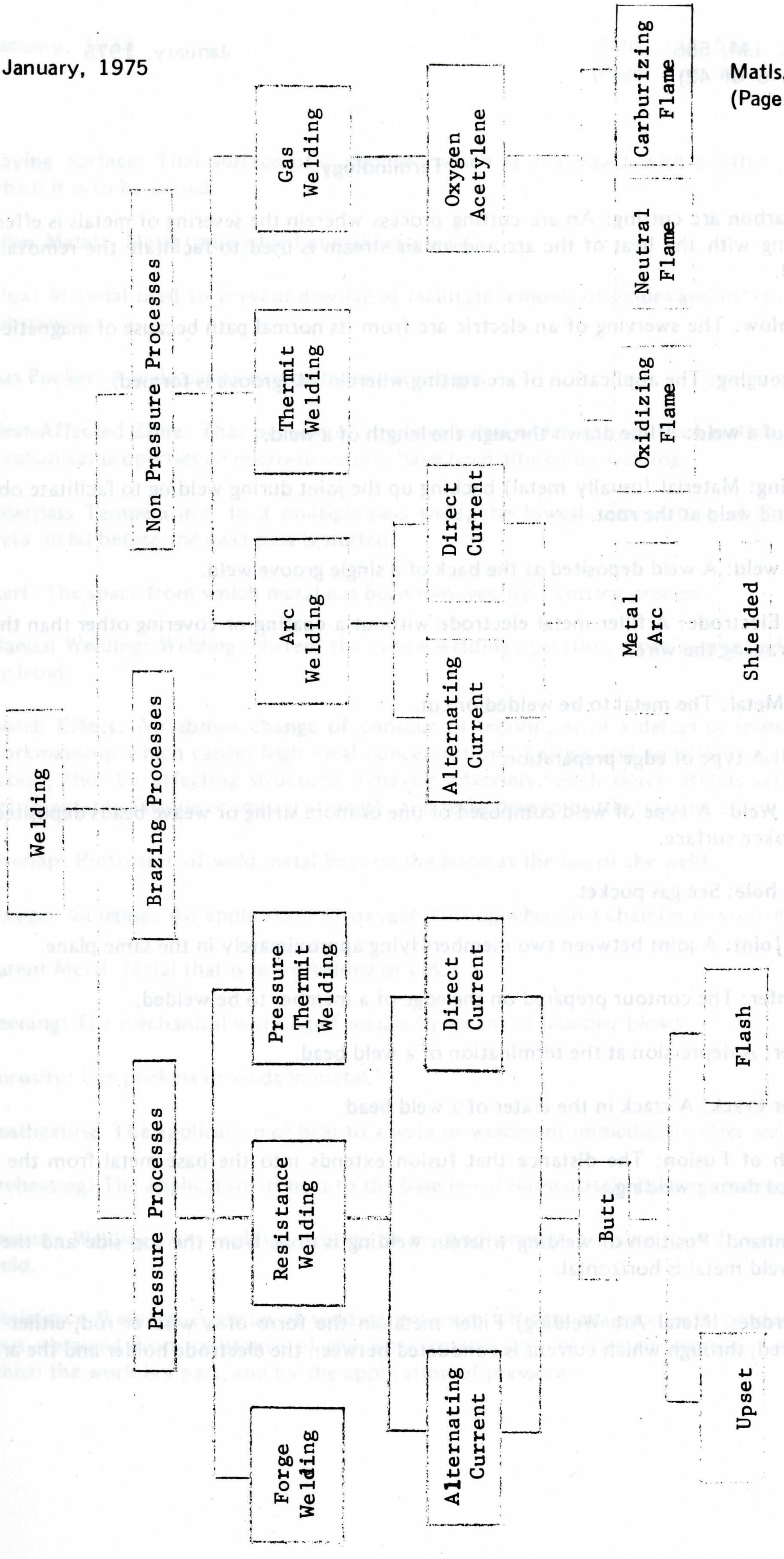
Pressure (Resistance) Welding

Resistance welding may be done with either alternating current or direct current. The type of current used will either be designated in the welding procedure specification or left up to the welder to decide for himself.

Resistance welding can be seen on shear stud connectors on bridge beams. This type of resistance welding varies somewhat from others in that a flux tip is used on the stud plus a heat-resistant ceramic arc shield (ferrule). The flux tip acts as a deoxidizer and arc stabilizer for the welding while the ferrule holds the molten metal an a prescribed area as the pressure is applied and coalescence takes place.

Non Pressure Welding

Arc welding is one of the most common and widely known forms of welding in use today so it is not surprising to find that most of our problems deal with this type of welding, both in the field and in the fabricating shop since this manual is written for the sole purpose of inspection of arc welding.


Welding
Non Pressure Processes
Brazing Processes
Pressure Processes
Gas Welding
Thermit Welding
Arc Welding
Pressure Thermit Welding
Resistance Welding
Forge Welding
Oxygen Acetylene
Direct Current
Alternating Current
Direct Current
Alternating Current
Carburizing Flame
Neutral Flame
Oxidizing Flame
Metal Arc
Shielded
Butt
Flash
Upset

Terminology

Air carbon arc cutting: An arc cutting process wherein the severing of metals is effected by melting with the heat of the arc and an air stream is used to facilitate the removal of the metal.

Arc blow: The swerving of an electric arc from its normal path because of magnetic forces.

Arc gouging: The application of arc cutting wherein a U-groove is formed.

Axis of a weld: A line drawn through the length of a weld.

Backing: Material (usually metal) backing up the joint during welding to facilitate obtaining a sound weld at the root.

Back weld: A weld deposited at the back of a single groove weld.

Bare Electrode: A filler metal electrode without a coating or covering other than that used for drawing the wire.

Base Metal: The metal to be welded or cut.

Bevel: A type of edge preparation.

Bead Weld: A type of weld composed of one or more string or weave beads deposited on an unbroken surface.

Blow hole: See gas pocket.

Butt Joint: A joint between two members lying approximately in the same plane.

Chamfer: The contour prepared on the edge of a member to be welded.

Crater: A depression at the termination of a weld bead.

Crater Crack: A crack in the crater of a weld bead.

Depth of Fusion: The distance that fusion extends into the base metal from the surface melted during welding.

Downhand: Position of welding wherein welding is done from the top side and the axis of the weld metal is horizontal.

Electrode: (Metal Arc Welding) Filler metal in the form of a wire or rod, either bare or covered, through which current is conducted between the electrode holder and the arc.

Faying Surface: That surface of a member which is in contact with another member to which it is to be joined.

Filler Metal: Metal to be added in making a weld.

Flux: Material used to prevent dissolve or facilitate removal of oxides and other undesirable substances.

Gas Pocket: A weld cavity caused by entrapped gas.

Heat-Affected Zone: That portion of the base metal which has not been melted, but whose mechanical properties or micro-structures have been altered by welding.

Interpass Temperature: In a multiple-pass weld, the lowest temperature of the deposited weld metal before the next pass is started.

Kerf: The space from which metal has been removed by a cutting process.

Manual Welding: Welding wherein the entire welding operation is performed and controlled by hand.

Notch Effect: An abrupt change of contour or section, or of a defect or imperfection in workmanship which causes high local concentration of stress and constraint against ductile action, thereby affecting structural behavior adversely. Such notch effects are especially detrimental to fatique or impact strength, and resistance to brittle fracture.

Overlap: Protrusion of weld metal beyond the bond at the toe of the weld.

Oxygen Gouging: An application of oxygen cutting wherein a chamfer or groove is formed.

Parent Metal: Metal that is to be welded or cut.

Peening: The mechanical working of metals by means of hammer blows:

Porosity: Gas pockets or voids in metal.

Postheating: The application of heat to a weld or weldment immediately after welding.

Preheating: The application of heat to the base metal immediately before welding.

Pressure Welding: Any welding process or method wherein pressure is used to complete the weld.

Resistance Welding: A group of welding processes wherein coalescence is produced by the heat obtained from resistance of the work to the flow of electric current in a circuit of which the work is a part, and by the application of pressure.

Reverse Polarity: The arrangement of direct-current arc-welding leads wherein the work is the negative pole and electrode is the positive pole of the welding arc.

Root Opening: The separation between the members to be joined, at the root of the joint.

Root Face: That portion of the groove face adjacent to the root of the joints.

Root of Joint: The portion of a joint to be welded where the members approach closest to each other. In cross-section the root of the joint may be either a point, a line or an area.

Root of Weld: The point, as shown in cross-section, at which the bottom of the weld intersects the base metal surfaces.

Run-off Tab: Plates having the same joint preparation as the joint to be welded and placed on the end of the joint to carry the weld on past the end of the welded joint.

Semi-Automatic Arc Welding: Arc welding with equipment which controls only the filler metal feed. The advance of the welding is manually controlled.

Shielded Metal-Arc Welding: An arc-welding process wherein coalescence is produced by heating with an electric arc between a covered metal electrode and the work. Shielding is obtained from the decomposition of the electrode covering. Pressure is not used and filler metal is obtained from the electrode.

Size of Weld:

A. **Groove Weld**. The joint penetration (depth of chamfering plus the root penetration when specified).

B. **Fillet Weld**. For equal-leg fillet welds, the leg length of the largest isosceles right triangle which can be inscribed within the fillet-weld cross-section.

Slag Inclusion: Non-metallic solid material entrapped in weld metal or between weld metal and base metal.

Spatter: The metal particles expelled during welding and which do not form a part of the weld metal.

Straight Polarity: The arrangement of direct-current arc-welding leads wherein the work is positive and the electrode is the negative of the welding arc.

Stringer Bead: A type of weld bead made without appreciable transverse oscillation.

Tack Weld: A weld made to hold parts of a weldment in proper alignment until the final welds are made.

Underbead Crack: A crack in the heat-affected zone not extending to the surface of the base metal.

Undercut: A groove melted into the base metal adjacent to the toe of a weld and left unfilled by weld metal.

Weave Bead: A type of weld bead made with transverse oscillation.

Weld Metal: That portion of a weld which has been melted during welding.

Welder: One who is capable of performing a manual or semi-automatic welding operation.

Welder Certification: Certification in writing that a welder has produced welds meeting prescribed standards.

Welding Procedure: The detailed methods and practices, including joint welding procedures, involved in the production of a weldment.

Welder Qualification: The demonstration of welder's ability to produce welds meeting prescribed standards.

Welding Sequence: The order of making the welds in a weldment.

Weldor: See welder.

Weldment: An assembly whose component parts are joined by welding.

Weldment Defect: The failure of any weldment to meet the specifications.

SECTION III

Essentials

The inspector acts as the judicial representative of the Highway Commission and it is his responsibility to judge the quality of the welding and workmanship in relation to the outlined specifications. Although the inspector must strive for the best quality he must not delay the contractor without just cause.

Welding Knowledge

While actual welding experience is valuable to an inspector it is not one of the necessary essentials. The inspector should have sufficient knowledge of the welding process to enable him to know what defects are most likely to occur. He should have a general knowledge of current settings and welding techniques. He must be familiar with the procedure specifications, and know how to apply them.

Knowledge of Test Methods

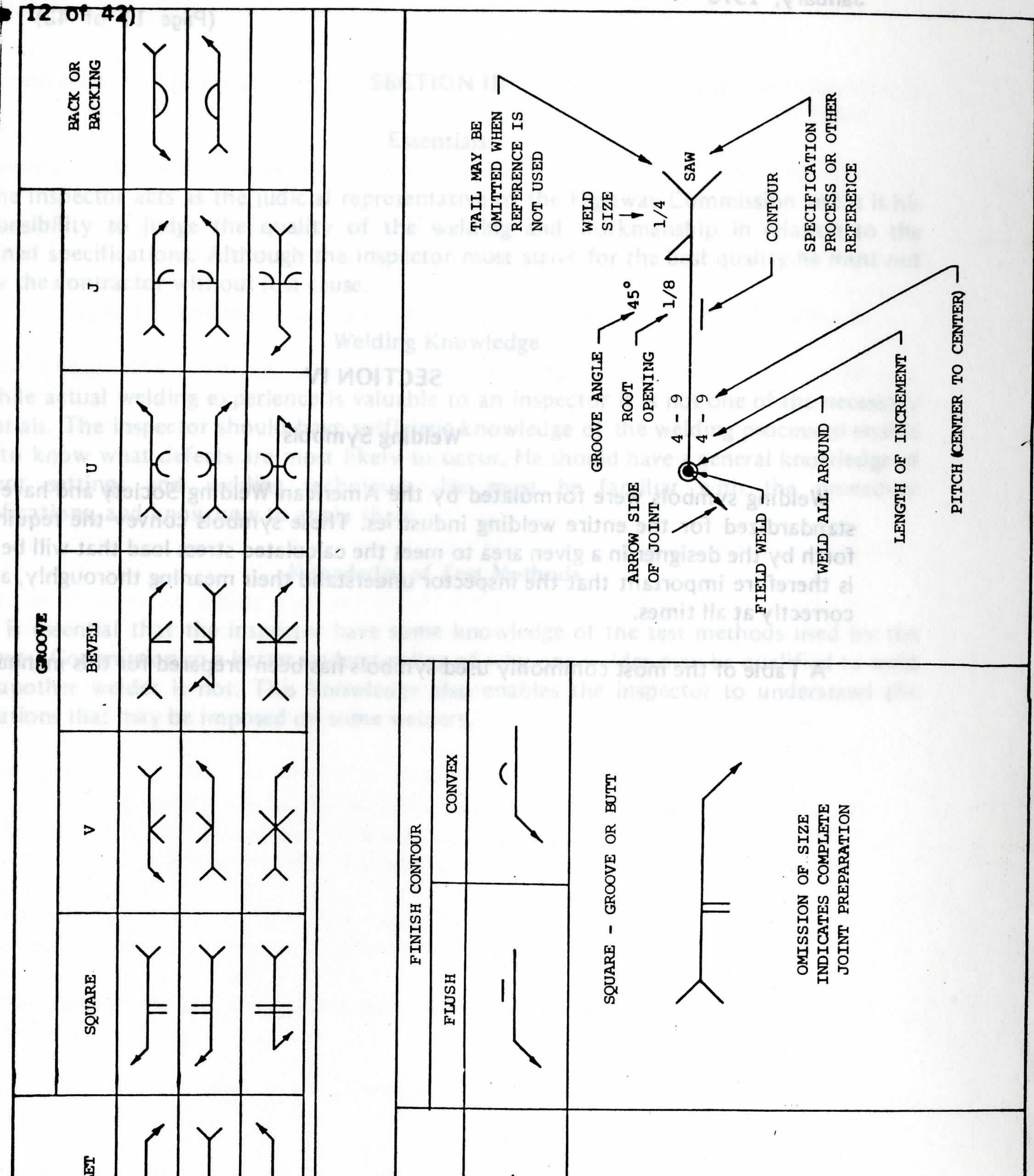
It is essential that the inspector have some knowledge of the test methods used by the Highway Commission so a better understanding of why one welder may be qualified to weld and another welder is not. This knowledge also enables the inspector to understand the limitations that may be imposed on some welders.

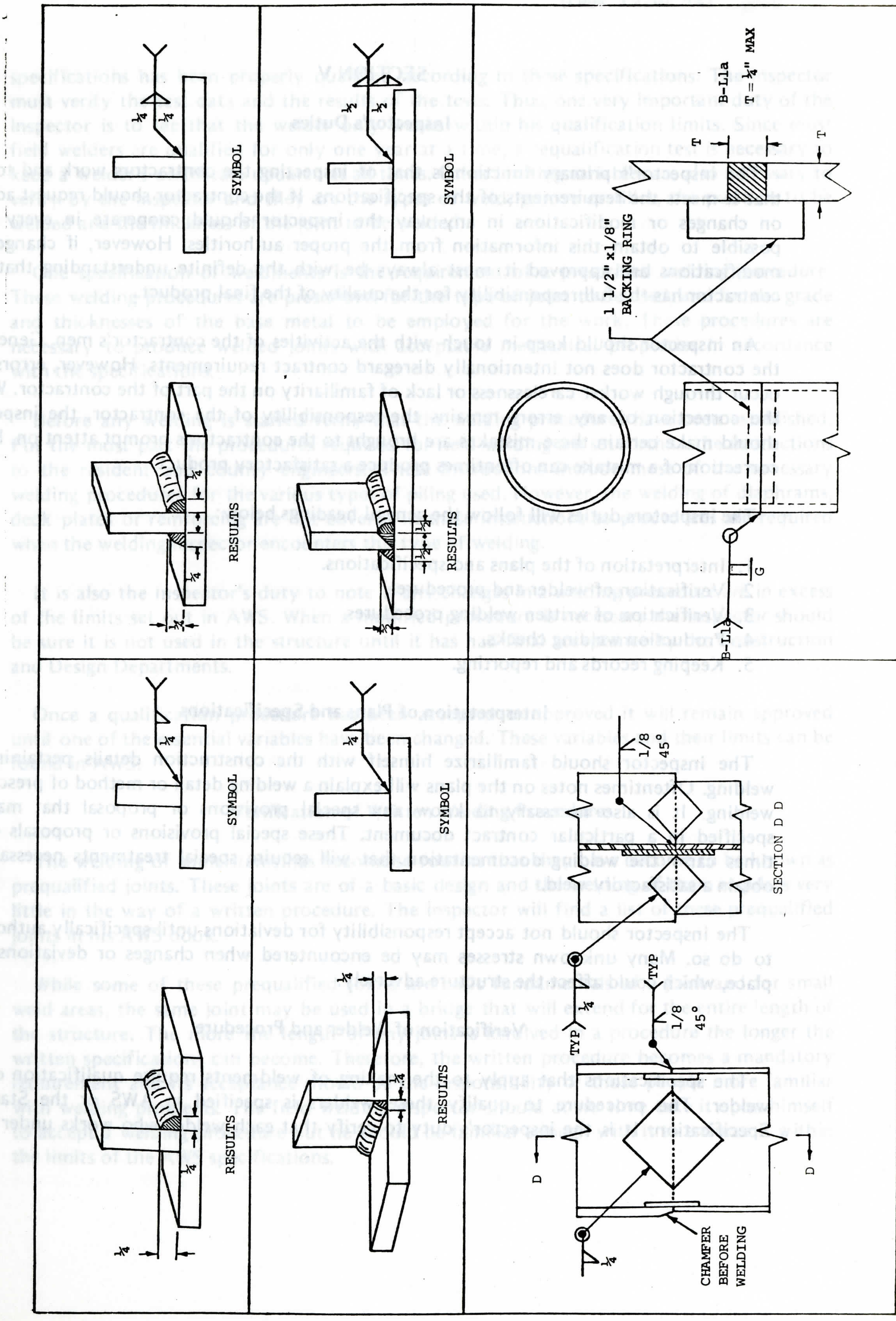
SECTION IV

Welding Symbols

Welding symbols were formulated by the American Welding Society and have since been standardized for the entire welding industries. These symbols convey the requirements set forth by the designer in a given area to meet the calculated stress load that will be applied. It is therefore important that the inspector understand their meaning thoroughly, and apply it correctly at all times.

A Table of the most commonly used symbols has been prepared for this manual.


LOCATION
ARROW SIDE
OTHER SIDE
BOTH SIDES
FILLET
GROOVE
SQUARE
V
BEVEL
U
J
BACK OR BACKING
WELD ALL AROUND
FIELD WELD
FINISH CONTOUR
FLUSH
CONVEX
TAIL MAY BE OMITTED WHEN REFERENCE IS NOT USED
WELD SIZE
1/4
SAW
CONTOUR
SPECIFICATION PROCESS OR OTHER REFERENCE
GROOVE ANGLE
45°
ROOT OPENING
1/8
4 - 9
4 - 9
ARROW SIDE OF JOINT
FIELD WELD
WELD ALL AROUND
LENGTH OF INCREMENT
PITCH (CENTER TO CENTER)
COMBINED WELDS
1/4
1/8
60°
1/4
SQUARE - GROOVE OR BUTT
OMISSION OF SIZE INDICATES COMPLETE JOINT PREPARATION


SYMBOL
RESULTS
SYMBOL
RESULTS
1 1/2" x 1/8"
BACKING RING
B-L1a
T = 1/4" MAX
G
SYMBOL
RESULTS
SYMBOL
RESULTS
TYP
1/8
45°
SECTION D D
D
D
CHAMFER
BEFORE
WELDING

SECTION V

Inspector's Duties

The inspector's primary function is that of inspecting the contractors work and to see that it meets the requirements of the specifications. If the contractor should request advice on changes or modifications in any way the inspector should cooperate in every way possible to obtain this information from the proper authorities. However, if changes or modifications are approved it must always be with the definite understanding that the contractor has the full responsibility for the quality of the final product.

An inspector should keep in touch with the activities of the contractor's men. Generally the contractor does not intentionally disregard contract requirements. However, errors can occur through worker carelessness or lack of familiarity on the part of the contractor. While the correction of any errors remains the responsibility of the contractor, the inspector should make certain these mistakes are brought to the contractor's prompt attention. Early correction of a mistake can oftentimes produce a satisfactory product.

The inspectors duties will follow the general headings below:

1. Interpretation of the plans and specifications.
2. Verification of welder and procedure.
3. Verification of written welding procedures.
4. Production welding checks.
5. Keeping records and reporting.

Interpretation of Plans and Specifications

The inspector should familiarize himself with the construction details pertaining to welding. Oftentimes notes on the plans will explain a welding detail or method of prescribed welding. It is also necessary to know any special provisions or proposal that may be specified in a particular contract document. These special provisions or proposals often times carry the welding documentation that will require special treatments necessary to obtain a satisfactory weld.

The inspector should not accept responsibility for deviations until specifically authorized to do so. Many unknown stresses may be encountered when changes or deviations take place, which could affect the structure adversely.

Verification of Welder and Procedure

The specifications that apply to the making of weldments require qualification of the welder. The procedure to qualify these welders is specified in AWS or the Standard Specification. It is the inspector's duty to verify that each welder who works under these specifications has been properly qualified according to these specifications. The inspector must verify the test data and the results of the tests. Thus, one very important duty of the inspector is to see that the welder only works within his qualification limits. Since most field welders are qualified for only one year at a time, a requalification test is necessary to keep a welder's certificate updated at all times. Other limiting variables are also necessary to verify by the inspector and they are the types of weld, groove or fillet, the position to be welded and the thickness of the joint to be welded.

One specification of weldments is the requirement of a prescribed welding procedure. These welding procedures are prescribed for the type of joint to be used, and for the grade and thicknesses of the base metal to be employed for the work. These procedures are necessary to produce welded joints with acceptable mechanical properties in accordance with the specifications.

Before any welding is started verify that the welding procedures have been established. For the most part the procedures required for field welding are set forth in the instructions to the resident and county engineers. These instructions include most of the necessary welding procedures for the various types of piling used. However, the welding of diaphrams, deck plates or reinforcing are not covered in these instructions so procedures are required when the welding inspector encounters this type of welding.

It is also the inspector's duty to note if any changes in a welding procedure are in excess of the limits set out in AWS. When a modified procedure is necessary the inspector should be sure it is not used in the structure until it has had final acceptance by the Construction and Design Departments.

Once a qualification procedure has been accepted or approved it will remain approved until one of the essential variables have been changed. These variables and their limits can be found in AWS.

Verification of Written Welding Procedures

The welding of some items has become so routine that they have become to be known as prequalified joints. These joints are of a basic design and the welding of them requires very little in the way of a written procedure. The inspector will find a list of these prequalified joints in his AWS book.

While some of these prequalified joints are basic fundamentals of a joint and for small weld areas, the same joint may be used in a bridge that will extend for the entire length of the structure. The more the length of any joint is involved in a procedure the longer the written specifications can become. Therefore, the written procedure becomes a mandatory requirement and its acceptance should be the responsibility of those people more familiar with welding problems. The field welding inspector should at no time take it upon himself to accept a welding procedure but he should be familiar enough with it to enforce it within the limits of the AWS specifications.

Not all welding procedures can be as simplified to the Resident and County Engineer as the welding of piling instructions have been. However, certain basic ideas can and are simplified in AWS. Additional basic procedures will be outlined later in this manual.

Selection of Production Test Samples

Not very often does a specification call for production test samples on field welding, but it does happen on occasions and therefore the inspector must have an idea of what is expected in taking these samples. The specification will state if the production test is to be non-destructive or otherwise. It will also state what type of non-destructive test is to be performed.

When non-destructive tests are to be performed it will undoubtedly be in the form of radiographic inspection. The number or frequency of radiographs to be taken will be included in the specification document. However, when spot radiographic inspection is called for the inspector may be required to make the decision of when the radiographic inspection is to be made. These tests may be made by chance or in accord with an established order. In either case the contractor and the state are definitely concerned about new welders and some early radiographic inspection is highly desirable, followed by less frequent inspection once the welder has proven his consistent ability.

Additional non-destructive testing may be performed by magnafluxing, trepanning, metallurgical examination, mechanical testing to destruction of run off tabs or other detailed examinations.

Records and Reports

Any work performed in the field that requires inspection or tests will also require records. However, required or not, an inspector should keep a good record of his work. This may be in the form of a set of notes or as detailed as the Resident Engineer requires.

It is also the inspector's duty to check all records for detailed accuracy, in accordance with the contract documents, and to have them available when required. Any records that may require a contractor's signature should be prepared by the contractor and not by the inspector.

SECTION VI

Specifications for Welding Procedures

Many factors contribute to the end result of any welding operation. Because of the complexity it is desirable and essential that the vital parts, associated with the welding of a joint, are properly detailed to permit a clear understanding of the intended weld to all concerned. Generally, welding procedures have to be proved adequate by either qualification tests or enough prior use and experience to guarantee dependability. The sole purpose of welding procedures is to describe the details that are to be followed in the welding of specific materials or type of joints.

Description and Details

The details of a welding procedure specification when written must be in accordance with the contract specifications and within good welding practice. They must be sufficiently detailed to insure welding that will satisfy the contract specifications.

Following is a list of details that are normally covered in a welding procedure specification for the shielded metal-arc process. Other welding processes may have some specification changes of varying degrees, and if ever found used in the field a reference to AWS will most certainly be needed.

Welding Process - Shielded Metal-Arc

Filler Metal - Unless otherwise specified in the contract the electrodes shall be E-7016, E-7018, E-6010, E-6011 or E-7028.

Base Metal - ASTM A-36 structural steel; ASTM A-252 steel pipe SAE 1010 steel pipe; SAE 1000 corrugated steel pipe.

Type of current - AC, DC reverse (electrode positive) or DC straight (electrode negative).

Joint Design - Single bevel (with or without backing) double bevel, square butt welds, or fillet welds, and the thickness of the base metal.

Welder qualification - Welder qualified by tests given by the Iowa State Highway Commission.

Joint Preparation and smoothness - Oxygen cutting to the design outlined on the P10 A standard and the tolerance and smoothness outlined in Instruction to the Resident and County Engineers No.12 Section XXI.

Joint Welding Design - Details that influence weld quality in terms of specification requirements such as; Welding the web first on H piling. These details help determine the soundness of welds, and influence the structural properties of the finished joint.

Welding Position - Such as flat, horizontal, vertical or overhead.

Preheat Temperature - Unless otherwise specified in the contract documents the preheat temperature shall be as specified in the AASATO standard specifications.

Interpass Temperature - Equal to minimum preheat temperature at all times. Maximum temperature is not critical provided the heat input during welding is not excessive. However, if heat treated steels are used the maximum temperature will be found in the AASHTO standard specifications or the contract documents.

Additional Details

Some additional details that may not be mentioned in the welding procedure specification but still have adverse effects on the welding joint are summarized in the following paragraphs.

The indiscriminate use of peening a weld should not be permitted. Peening can be very detrimental to a weld if not properly used. However, the inspector should not confuse the use of the chipping hammer with the use of peening a weld. Chipping hammers are required for the cleaning of slag from a weld. A more detailed description of peening is covered later in this manual under Section (XI) Welding Metallurgy.

Excessive heat input during welding can also be detrimental to a weld. Therefore a controlled heat input is a must for a good weld. Cracks may result from welding processes involving large heat inputs. In the arc welding process the heat input is lowered by reducing the current or by increasing the travel speed while maintaining the same current level. This explanation then reveals to us that, the stringer bead is far superior to the weaving method in which the forward travel speed is drastically reduced while the current level remains constant.

When a weld is not completely satisfactory upon completion, local sections may have to be removed for repair. This shall be done by one or by a combination of the following approved processes; grinding, oxygen cutting, or air arc. These are the same methods that are permitted in preparing the joint the first time. Details of the repair weld shall be made by the same process and procedures as the initial weld.

Non-destructive testing of field welds is not made unless called for in the project specifications or directed by the Engineer. Visual inspection of the welding is normally all that is required to be made by the inspector.

Postheat treatment of welds on structures are sometimes performed by a heat treatment or annealing process in order to develop the required mechanical properties or dependability as required. While this does not apply to the ordinary field welding work there are occasions when it has been called for. When postheat treatment is necessary it shall be part of the procedure specification and the inspector will be required to make sure the temperature is within the limits specified by the use of temperature sticks.

Welding procedure specifications are usually called for on the contract documents and then established by the contractor. Procedures that have the same basic fundamentals have been deemed as prequalified by AWS and the essential variables have been outlined in the instruction to Resident Engineers by the Construction Department. In this way definite welding procedures have been established for the welding of piling and all contractors follow the same procedures.

SECTION VII

Weldment Defects

Weldment defects can be classified into three groups:

1. Drawing or dimensional variations.
2. Structural discontinuities within the weld.
3. Physical or chemical properties of the weldment.

Drawing or Dimensional Defects

The making of satisfactory welds in regard to dimensional defects depends upon keeping within the specified dimensions for the size and shape of welds and the finished dimensions of the product. Departure from the dimensions in any respect should be regarded as dimensional defects and must be corrected before the final acceptance of the weldment can be made. Defects of this nature may be further subdivided as follows:

(a) **Incorrect Joint preparation:**

Established welding procedures require proper joint dimensions and preparation for each joint according to the thickness of the material being welded. The failure of an inspector to require this criteria may result in a greatly increased tendency to produce the weld defects listed under structural discontinuities within the weld. Therefore it is very important that all joint preparations are the same as shown in the specifications. (See Figure 1)

(b) **Incorrect weld Profiles and size:**

The profile of a finished weld can have a considerable effect upon its performance under load. The profile of one layer of a multipass weld can have an effect on the next pass in that it may cause slag inclusions or incomplete fusion to occur between the passes. Requirements concerning these defects are in AWS under the article entitled Weld Profiles and the inspector should have a good working knowledge of them. Failure to conform to these requirements constitutes a weld defect. Permissible tolerances and corrections for these various defects will also be found in AWS under articles "Quality of Welds" and "Corrections".

Overlap is a condition which tends to produce notches which are dangerous, due to the resultant concentrated stress under load. It is considered defective welding because the effective size of the fillet is reduced. It is also very hard for an inspector to be sure of the true fillet size, since the true size is governed by inscribing an isosceles right triangle inside

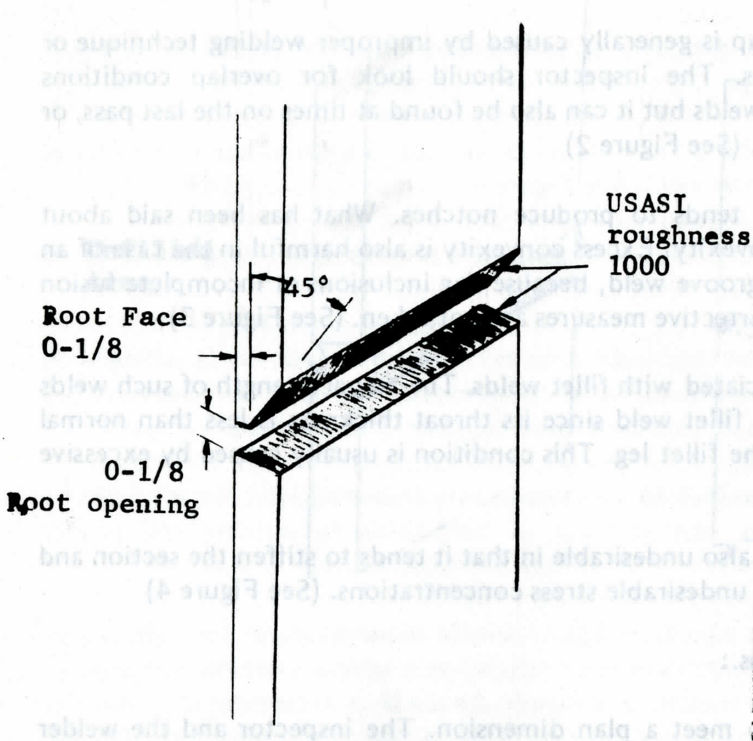
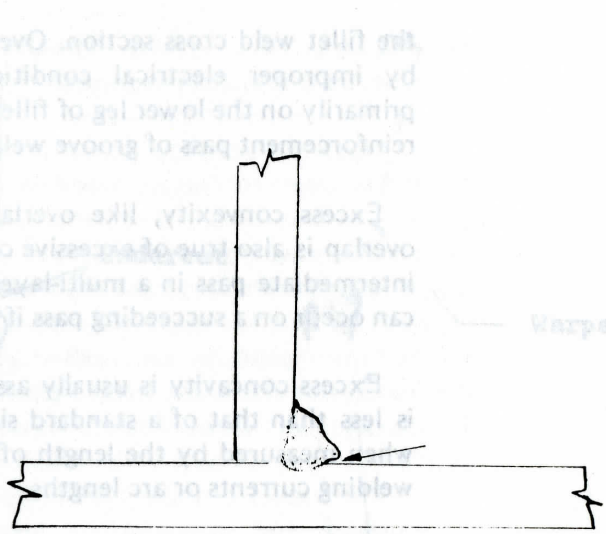


Figure 1



Fillet weld overlap

Figure 2

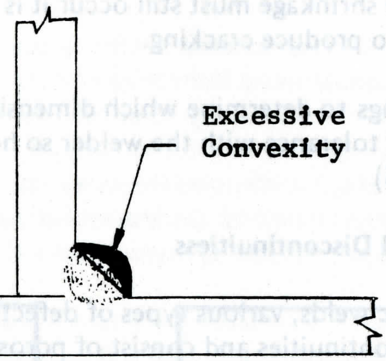


Figure 3

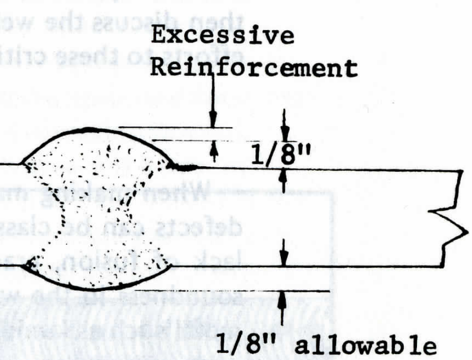


Figure 4

the fillet weld cross section. Overlap is generally caused by improper welding technique or by improper electrical conditions. The inspector should look for overlap conditions primarily on the lower leg of fillet welds but it can also be found at times on the last pass, or reinforcement pass of groove welds. (See Figure 2)

Excess convexity, like overlap, tends to produce notches. What has been said about overlap is also true of excessive convexity. Excess convexity is also harmful in the case of an intermediate pass in a multi-layer groove weld, because slag inclusions or incomplete fusion can occur on a succeeding pass if corrective measures are not taken. (See Figure 3)

Excess concavity is usually associated with fillet welds. The actual strength of such welds is less than that of a standard size fillet weld since its throat thickness is less than normal when measured by the length of the fillet leg. This condition is usually caused by excessive welding currents or arc lengths.

Excessive weld reinforcement is also undesirable in that it tends to stiffen the section and establishes notches that help create undesirable stress concentrations. (See Figure 4)

(c) **Incorrect final dimensions.:**

All weldments are fabricated to meet a plan dimension. The inspector and the welder must be aware of how much shrinkage can be expected at each weld joint and how much warpage will occur in the joint.

If the inspector visualizes the welding of a simple V on a simple plate and knows that the welding heat causes shrinkage in each pass then he can also visualize the ends of the plate curling up. This heat shrinkage is what causes weld warpage.

On welds that are designed to prevent shrinkage and warpage or welds that are restricted by manual devices it is obvious that while shrinkage must still occur it is restricted and thus produces shrinkage stresses that will tend to produce cracking.

The inspector should review the drawings to determine which dimensions are critical and then discuss the weldment dimensions and tolerance with the welder so he will devote major efforts to these critical areas. (See Figure 5)

Structural Discontinuitiess

When making manual shielded metal-arc welds, various types of defects may occur. These defects can be classified as structural discontinuities and consist of porosity, slag inclusions, lack of fusion, cracks etc. This terminology is used here to denote an interruption in the soundness in the weld metal itself and not a change in the metallographic structure of the metal such as laminations, scabs etc.

Porosity is gas pockets or voids in the weld metal which are free of any solid material, such as slag. It is formed as a result of gases driven from the weld metal by chemical

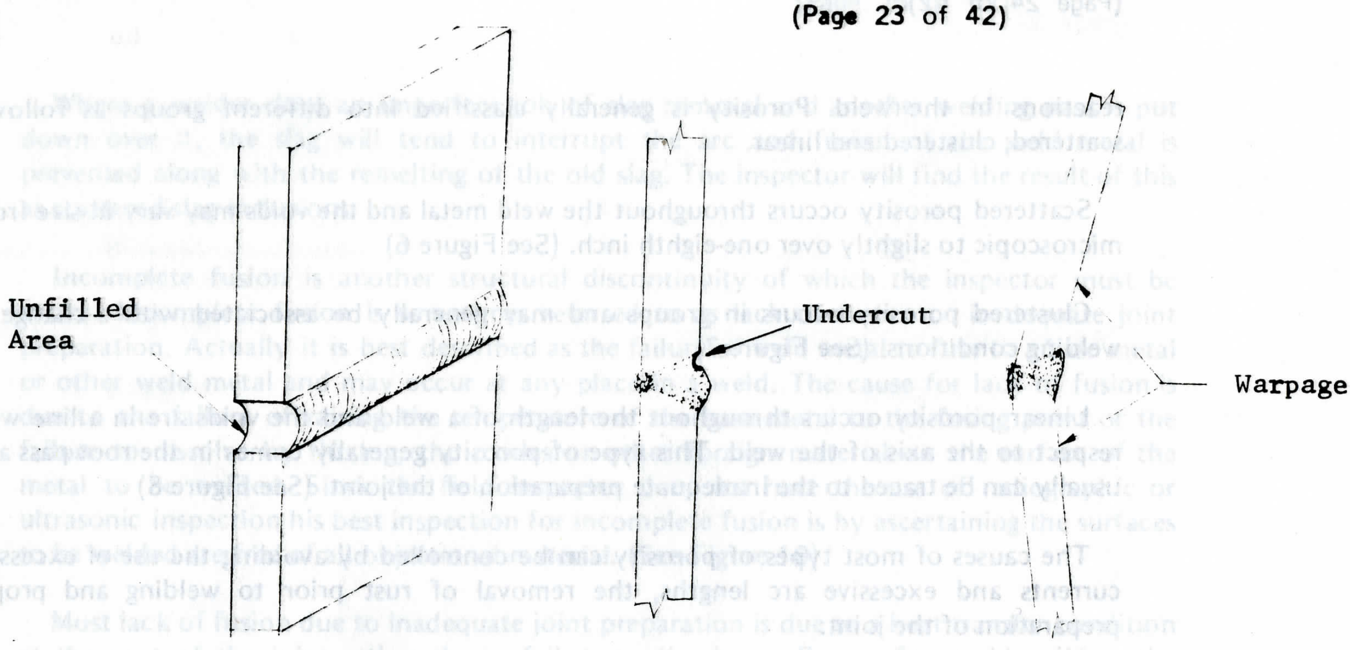
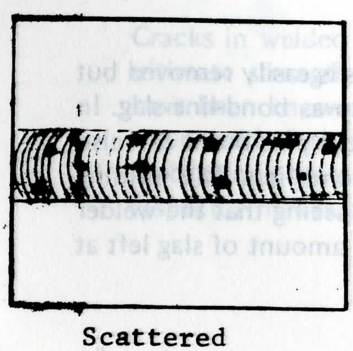


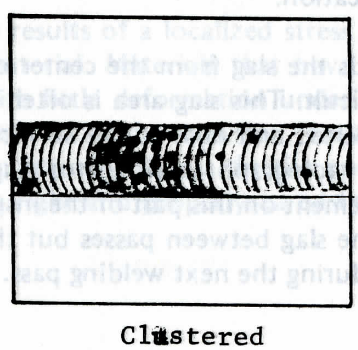
Figure 5



Scattered

Porosity

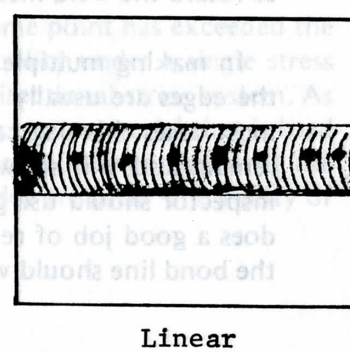
Figure 6



Clustered

Porosity

Figure 7



Linear

Porosity

Figure 8

reactions in the weld. Porosity is generally classified into different groups as follows; scattered, clustered and linear.

Scattered porosity occurs throughout the weld metal and the voids may vary in size from microscopic to slightly over one-eighth inch. (See Figure 6)

Clustered porosity occurs in groups and may generally be associated with a change in welding conditions. (See Figure 7)

Linear porosity occurs throughout the length of a weld and the voids are in a line with respect to the axis of the weld. This type of porosity generally comes in the root pass and usually can be traced to the inadequate preparation of the joint. (See Figure 8)

The causes of most types of porosity can be controlled by avoiding the use of excessive currents and excessive arc lengths, the removal of rust prior to welding and proper preparation of the joint.

Slag inclusions are entrapped non-metallic solids in or near the weld metal and vary in size and location. Slag in molten weld metal will rise to the surface unless restrained by another force. In welding by the shielded metal-arc process and covered electrodes slag may be formed or forced below the surface of the molten metal by the stirring action of the electric arc. Slag can also flow ahead of the arc and thus cause metal to be deposited over it.

Slag can also form on a root pass of a V weld if the root opening is too small to permit the arc to heat the bottom of the recess to a high enough temperature to allow the slag to float to the surface. (See Figure 9). The welder can create similar conditions to this by having undercutting or excessive convexity in a weld bead, or using too large an electrode in the root pass. This type of slag inclusion is elongated and usually of considerable size and thus the strength of the joint is reduced considerably.

When slag is forced into the molten metal or formed there by chemical reaction, its appearance is the same as porosity on a radiographic film. Slag of this type is most likely found in overhead welding.

The inspector should realize that most slag can be prevented by the welder using good sound welding practices, such as: Proper preparation of the groove before each weld bead is deposited. Use care to correct contours that are outside specifications and the use of preheat to retard the weld metal solidification.

In making multiple pass welds the slag from the center of the pass is easily removed but the edges are usually more difficult. This slag area is often referred to as bond-line slag. In most cases this slag can be remelted and raise to the surface in the next pass but it can also remain and will show up in a radiograph as elongated slag at the bond line. The welding inspector should use good judgement on this part of the inspection in seeing that the welder does a good job of removing the slag between passes but that a tiny amount of slag left at the bond line should work out during the next welding pass.

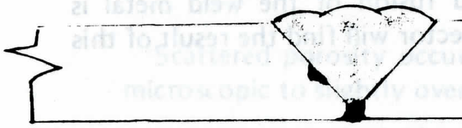
Where a welder does an imperfect job of slag removal and another welding pass is put down over it, the slag will tend to interrupt the arc and fusion of the weld metal is prevented along with the remelting of the old slag. The inspector will find the result of this as scattered slag inclusions.

Incomplete fusion is another structural discontinuity of which the inspector must be aware. Incomplete fusion is sometimes referred to as lack of fusion or inadequate joint preparation. Actually it is best described as the failure of weld metal to fuse to a base metal or other weld metal and may occur at any place in a weld. The cause for lack of fusion is due to the failure of raising the temperature of the base metal to the fusing point or the failure to dissolve by fluxing, the oxides or other foreign material on the surface of the metal to be welded. Since the field inspector does not have the use of radiographic or ultrasonic inspection his best inspection for incomplete fusion is by ascertaining the surfaces to be welded are free of all objectional material. (See Figure 10)

Most lack of fusion due to inadequate joint preparation is due to a heat transfer condition at the root of the joint rather than a failure to dissolve or flux surface oxides. When the portion of the base metal closest to the electrode is a considerable distance from the root the heat transfer will have to be made by conduction which may be insufficient to attain the fusion temperature at the root. An unfused root area is undesirable in that the unfused area permits stress concentration that could cause failure without appreciable deformation due to reduced section area. Even though the working stresses in the structure may not involve tension or bending, at some pile splice welds the shrinkage stresses can cause a crack to initiate at the unfused area. Such cracks may progress as additional weld layers are deposited until they extend through the entire thickness of the weld. The inspector's vigilance at the time of the joint preparation and assembly is the best protection he can give to prevent lack of fusion at the root area. However, this does not mean the inspector should not watch out for other elements that also can cause lack of fusion such as too large of electrodes, high rate of travel or the use of insufficient welding current.

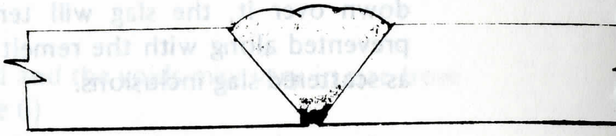
The term, undercut, is used primarily to describe the reduction of the base metal thickness at a line where the last bead of weld metal is fused to the surface or at the toe of a weld. It can occur on both groove and fillet welding but is most frequently found on the vertical leg of a horizontal fillet or the top side of a horizontal groove. Undercutting of both types is usually due to a technique employed by the welder, although magnetic arc blow can also be a factor. Undercutting can be detected by visual inspection and a tolerance for it has been set up in the AWS under the article entitled "Weld Profiles". (See Figure 11)

Cracks in welded joints are results of a localized stress that at some point has exceeded the ultimate strength of the material. Materials that have good ductility under a single stress have been known to fail with little deformation under a multi-directional stress system. As discussed before, the unfused area of the root may result in cracks. Any material that is hard or brittle is more subject to cracking than a ductile one, therefore it is important that the inspector makes certain the right and properly cared for electrodes are used. The ability of



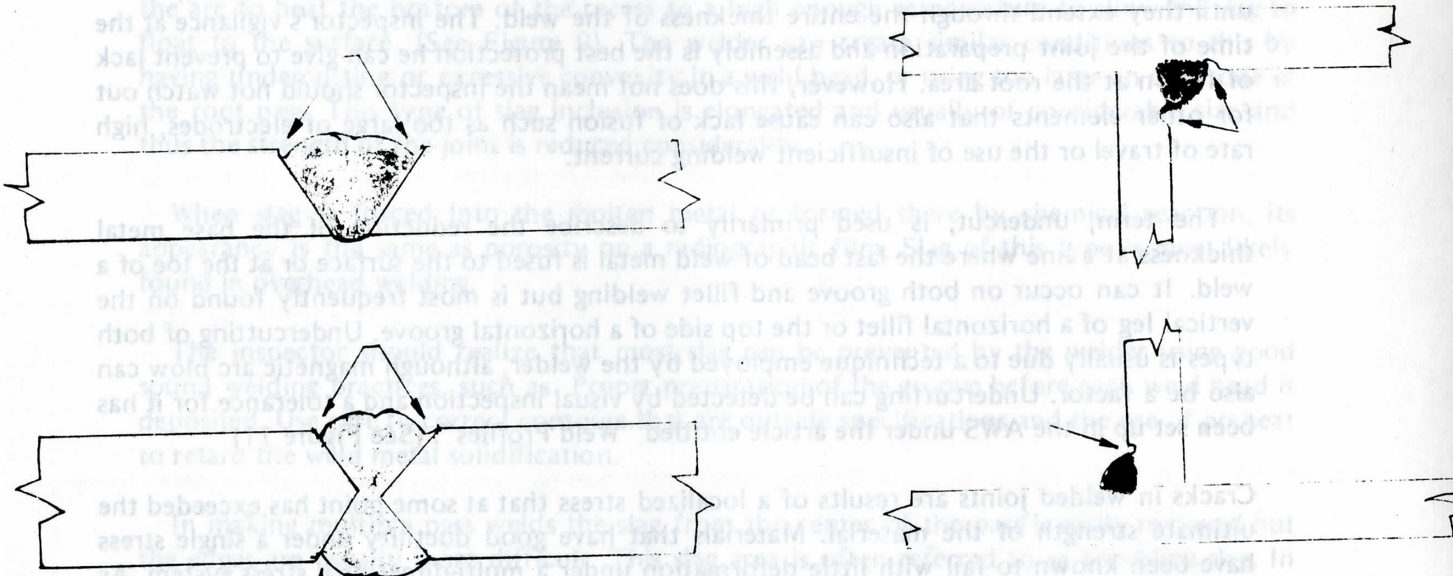
Inadequate Joint Preparation

Figure 9



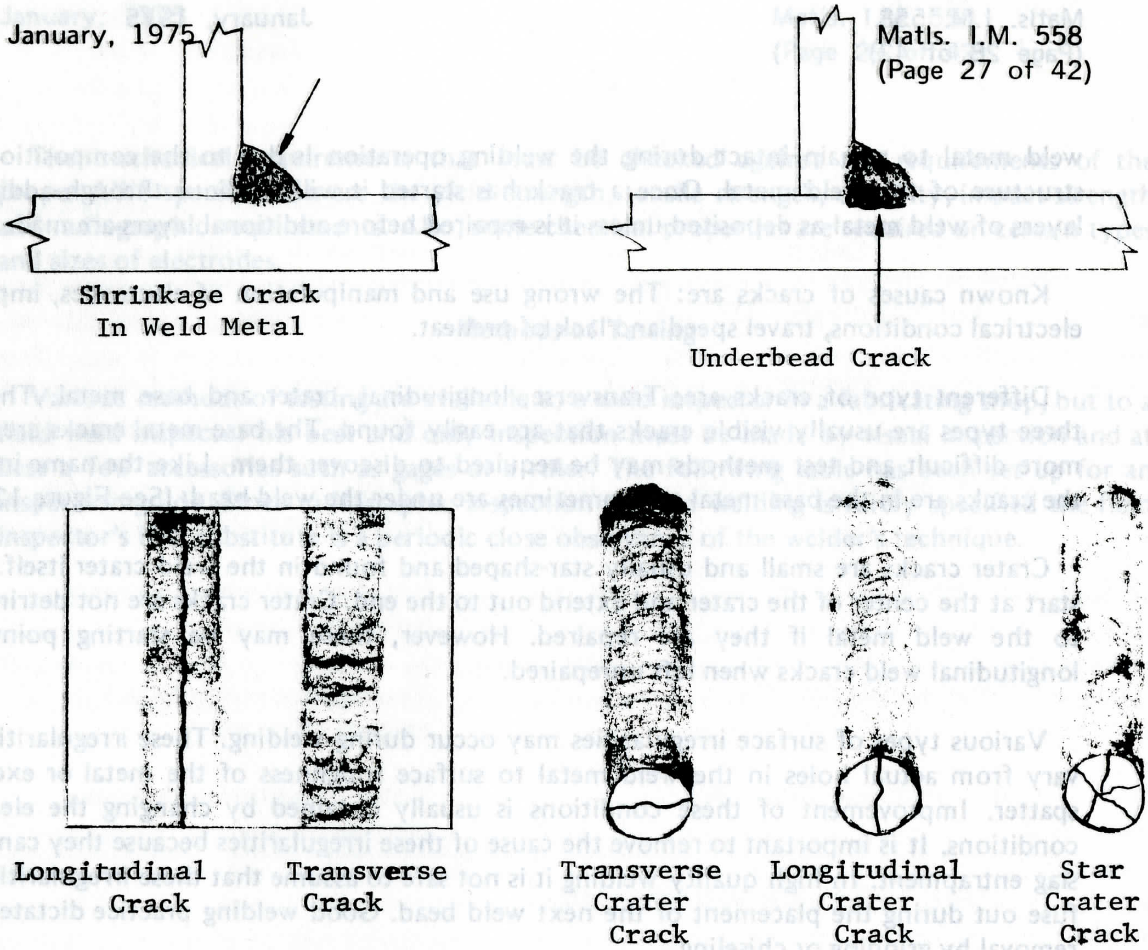
Incomplete Fusion

Figure 10



Undercutting on Groove and Fillet Welds

Figure 11



Various Types of Weld Metal Cracks

Figure 12

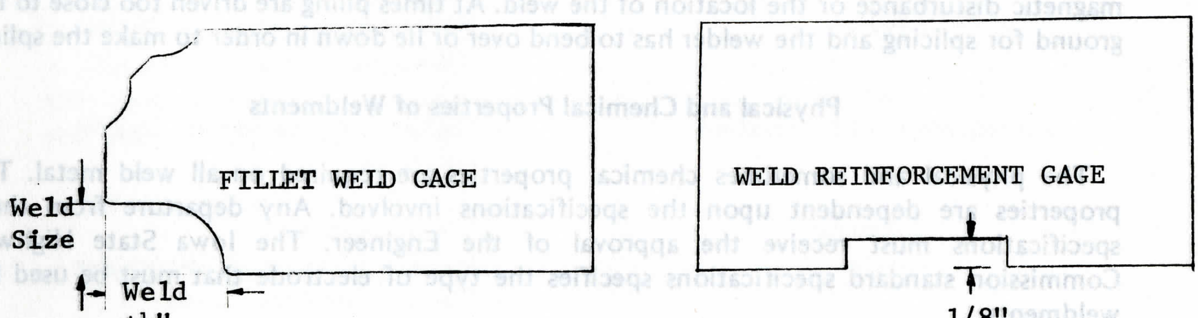


Figure 13

weld metal to remain intact during the welding operation is due to the composition and structure of the weld metal. Once a crack has started it will continue through additional layers of weld metal as deposited unless it is repaired before additional layers are made.

Known causes of cracks are: The wrong use and manipulation of electrodes, improper electrical conditions, travel speed and lack of preheat.

Different type of cracks are; Transverse, longitudinal, crater and base metal. The first three types are usually visible cracks that are easily found. The base metal cracks are much more difficult and test methods may be required to discover them. Like the name implies, the cracks are in the base metal and sometimes are under the weld bead. (See Figure 12)

Crater cracks are small and usually star-shaped and found in the weld crater itself. They start at the center of the crater and extend out to the end. Crater cracks are not detrimental to the weld metal if they are repaired. However, these may be starting points for longitudinal weld cracks when left unrepaired.

Various types of surface irregularities may occur during welding. These irregularities can vary from actual holes in the weld metal to surface roughness of the metal or excessive spatter. Improvement of these conditions is usually obtained by changing the electrical conditions. It is important to remove the cause of these irregularities because they can cause slag entrapment. In high quality welding it is not safe to assume that these irregularities will fuse out during the placement of the next weld bead. Good welding practice dictates their removal by grinding or chiseling.

The surface appearance of the weld generally reflects the ability and experience of a welder. The more uniform the weld bead surface the better the eye appeal. Good welding that is poorly finished should not be excused except under unusual conditions, even though the integrity of the job is beyond question. Such unusual conditions would be a great magnetic disturbance or the location of the weld. At times piling are driven too close to the ground for splicing and the welder has to bend over or lie down in order to make the splice.

Physical and Chemical Properties of Weldments

The physical and sometimes chemical properties are required on all weld metal. The properties are dependent upon the specifications involved. Any departure from these specifications must receive the approval of the Engineer. The Iowa State Highway Commission standard specifications specifies the type of electrode that must be used for weldments.

The Materials Department maintains a current list of approved electrode certifications and furnishes a list of these manufacturers and the electrode types as changes occur, to each of the District Materials offices and the Ames Construction Department. The welding inspector should refer to this list periodically to assure himself that the welder is using an approved electrode from an approved manufacturer.

The mechanical requirements that must be checked against the requirements of the proper AWS specification are the yield strength, tensile strength, ductility, impact strength and radiographic requirements. Also, some chemical properties are required on certain types and sizes of electrodes.

Methods of Testing

Various methods of testing are available to a weld inspector in a fabricating shop, but to a field weld inspector his best and only inspection must be made by visual inspection and at best a few accessories such as gages or a ruler. The following table has been set up for an inspection guide. Since radiographic inspection of field welding is rarely specified the field inspector's best substitute is a periodic close observance of the welder's technique.

Test for Welds

Defect	Methods of Testing
DIMENSIONAL DEFECTS	
Warpage	Visual inspection with proper mechanical gages.
Incorrect joint preparation	Visual inspection - Comparison with workmanship sample.
Incorrect weld size	Visual inspection with proper mechanical gages.
Incorrect weld profile	Visual inspection with proper mechanical gages.
Incorrect final dimensions	Visual inspection with proper mechanical gages.
STRUCTURAL DISCONTINUITIES	
Porosity	Radiographic - Magnetic Particle - Ultrasonic.
Slag Inclusions	Radiographic - Magnetic Particle - Ultrasonic.
Incomplete fusion	Radiographic - Magnetic Particle - Ultrasonic.
Inadequate joint preparation	Radiographic - Magnetic Particle - Ultrasonic.
Undercut	Visual inspection
Cracks	Visual inspection - Radiographic - Magnetic particle.
Surface Irregularities	Visual inspection - Comparison with workmanship sample.

SECTION VIII

Nondestructive Testing

The purpose of nondestructive testing is to detect weld discontinuities in weldments without impairing the usefulness of the material. There is an increasing growth in the use and types of testing available to the inspector. Currently, the methods accepted for weld inspection are visual, magnetic particle, liquid penetrant, radiographic, ultrasonic, eddy-current and leak and proof test techniques.

Under any one circumstances, one of these methods may be more suitable for that purpose than any one of the others.

Most nondestructive testing is expensive in that the operator of the equipment must be thoroughly trained and acquainted with the theory and application of the equipment. Therefore, the Design Department tries to eliminate any field welding in critical areas as much as possible and thereby relies on visual inspection for the majority of its field welding.

Visual Inspection

The visual inspection of weldments is of the first order of importance even when radiographic or other nondestructive means of testing is specified. It is the most important part of quality control. Visual inspection is also the most informative with regard to the general conformity of the weldment to specifications. It is the most extensively used of any method of inspection.

Visual inspection can be divided into four titles: Inspection skills, inspection before welding, inspection during welding and inspection after welding.

Skill

The field inspector should develop a definite procedure to insure adequate coverage of the various steps of welding. He must be familiar with the welding specifications, workmanship and all phases of welding.

Before welding

Details to check before the welding starts are:

1. The material to be welded.
2. Welder's qualification certificate.
3. Welder's equipment and electrodes.
4. Correct bevel and smoothness of edge preparation.
5. Root opening.
6. Clearance of backing strip or ring.

7. Overall alignment and fit up.
8. Welding procedure.

During welding

Details to check during the welding:

1. Preheat and interpass temperature.
2. Cleaning, chipping, grinding or gouging.
3. Structural discontinuities.
4. Postheating temperature when specified.

After welding

Details to check after the welding :

1. Dimensional accuracy of the weldment.
2. Conformity to drawing requirements.
3. Acceptability of welds with regard to appearance.
4. The presence of any unfilled craters, undercuts, cracks, overlaps.
5. Postheating temperature when specified.

Summary

Visual inspection is invaluable as an inspection method but caution must be used in drawing conclusions. The inspector should not judge a good surface appearance in itself as high weld quality, but rather base his judgement on evidence afforded by observations made prior to and during the welding along with the good weld appearance.

Gages and workmanship samples are also useful to the inspector and he should familiarize himself in their use. Gages can be readily made from a thin piece of sheet metal or cardboard if necessary. Figure 13 gives the basic dimensions necessary for simple gages.

SECTION IX

WELDING EQUIPMENT

Most field welding machines are portable, that is they are on a truck and can be moved around. The welding machine is usually a generator driven by a gasoline powered engine and puts out a D. C. current that may be reversed by changing the leads. The welding machine must contain a gauge or some means of determining the amperage output along with some method of increasing or decreasing the amperage as desired. The leads shall be in good conditions with unfrayed connections at both ends.

Good quality electrodes are a must. Welding manufacturers produce good quality electrodes that conform to the AWS A5.1 test requirements, however, this does not insure their good quality when delivered to the job site. The welder should discard any damaged electrodes. When he is using low hydrogen elecrrodes he must furnish them from undamaged hermetically sealed containers or have an oven for maintaining their dryness.

The welders cleaning tools should consist of a chipping hammer and a wire brush. A cold chisel and a hammer may be substituted for the chipping hammer.

A cutting torch must also be available for cutting, beveling and fitting up of the joints of field welds when required. A grinder is also necessary for smoothing out rough cuts and for the removal of a bad weld. Few welders are so skilled with a torch that grinding is not necessary.

The welder must have knowledge of the joint to be welded. Before welding, the inspector should check this knowledge against the information furnished to the Resident Engineer and make certain that it conforms to requirements outlined in these instructions.

The welder is also responsible for being able to verify that he has a valid Iowa State Highway Commission welding certificate.

Permissible Length of Welding Leads

Wire	Size	Diam. of each Wire - Mils	No. of Strands	Maximum (permissible) length of cable - ft.
1/0	0	74.5	19	100
2/0	00	83.7	19	150
3/0	000	94.0	19	225
4/0	0000	105.5	19	300

Typical Current Ranges for Electrodes in Ampers

Electrode Diam.-In.	E-6010 E-6011	E-7015 E-7016	E-7018	E-7028
3/32	40-80	65-110	70-100	-
1/8	75-125	100-150	115-165	140-190
5/32	110-170	140-200	150-220	180-250
3/16	140-215	180-255	200-275	230-305
7/32	170-250	240-320	260-340	275-365
1/4	210-320	300-390	315-400	335-430
5/16	275-425	375-475	375-470	-

Temperature Sticks

Fahrenheit Temperature Sticks by Tempil are available as follows:

6° increments	100°-350°	50° increments	650°-900°
12°-13° increments	350°-500°	Approx. 25° increments	900°-1050°
25° increments	500°-650°	50° increments	1050°-2500°

SECTION X

INSPECTORS RESPONSIBILITIES

Under Section V the duties of the inspector were described in a general way but detailed inspection was not spelled out. In Section VIII a detailed list of items was given as a check list for the inspector. It is now possible for the inspector to have familiarized himself with the inspection required and be able to follow the instruction to the Resident Engineer with a sense of responsibility.

Consultation with the welder is one responsibility the inspector should take care of as soon as he knows who the welder is going to be. If he can visit with the welder before he comes on the job this is even better than a discussion after his arrival. After having checked his certificate the class and polarity of the electrode should be discussed along with the proper preheat and interpass temperature. Consult with him on the need for proper joint preparation and fit-up. Give his first joint special attention so that he will use caution throughout the job.

Welding of Piling

The most important part of Highway field welding is the welding of piling and this entire manual is primarily devoted to welding the various types that are used. A description of the various types of piling and the welding of them is well defined in the latest revision of the Instructions to Resident and County Engineers. The inspector who follows the procedures outlined in the instructions will be able to carry out his inspection duties with great care. See Appendix A.

WELDING FOR SUPPORTING FLOOR FORM JOISTS

AND FINISHING MACHINE RAILS

The welding of supports for the use of floor joists and finishing machine rails consists of temporary welds only. The various items pertaining to these welds are explained in detail in the standard specifications under Article 2408.15. The inspector should refer to this specification when these supports are being placed and follow them carefully.

In the final inspection of the finished welds the inspector should be especially alert to look for open craters and undercutting of the bridge members. Any open craters and any undercutting in excess of the limits in AWS must be repaired.

WELDING OF DIAPHRAMS

Cleaning and Removal of Paint

On a bridge with a super elevated curve the diaphrams are oftentimes welded in place rather than bolted. The Design Department has preferred this method because of the variable location of each diaphram. Since the diaphrams do vary in location, some paint on the girder is usually where the diaphram should be and therefore must be removed. The method for removing the paint may be by either of the following methods; blasting, paint remover or burning. If either paint remover or burning is used a good stiff wire brushing must also be used for final cleanup. When the paint remover method is used a great deal of care must be exercised so no slopping or spilling on other areas takes place, therefore the other two methods are preferred.

Undercutting

The welding of a diaphrams consists of fillet welding in the horizontal, vertical and overhead positions (2F, 3F, & 4F). Since undercutting can occur in any of these positions the inspector should watch for it closely. The tolerance for permissible undercutting is outlined in the AWS Manual. The maximum permissible size of electrode for making fillets is outlined for manual shielded metal arc welding. The maximum size fillet weld which may be made in one pass shall be 5/16 inch in the horizontal or overhead position or 1/2 inch in the vertical position. In welding in the vertical position the progression of all passes shall be upward. These rules are also outlined under Article4.10 in the AWS D1.1 Manual.

Excessive Convexity

The convexity of a fillet weld profile shall not exceed 0.1S + 0.03 inch, where S equals the leg size of the fillet, Article 3.6 AWS D1.1. All excessive convexity and overlap fillets are to be corrected. Corrections for various types of defects are covered in AWS D1.1 Article 3.7.

Welding of Railroad Bridge Deck Floors

Railroad bridges that span highways are designed with a steel deck that covers the bridge and are welded together in the field. The special provisions that accompany railroad bridge lettings usually specify that a welding procedure be submitted for the field welding of the deck.

The welding procedure for the steel deck must not only cover the design of the welding joint, but it must also cover the sequence of welding. This welding procedure should receive the approval of the Design Department before welding is permitted.

Since railroad steel bridge decks vary in length, width and type of steel used it is somewhat difficult to have a standard welding procedure and sequence to cover them. Basically all the requirements necessary for writing the procedure and sequence are in AWS under Sections 2 & 3. The field inspector should understand the welding procedure and sequence thoroughly so he may help direct the welder in following the proper steps necessary.

Steel bridge decks involve longitudinal and transverse groove welds made in the flat position and are usually on plates of 1/2" thickness. Since welding is in both directions a multi-directional stress system can be built in if the procedure and sequence are not properly followed.

Welding of Reinforcing Steel

The welding of deformed reinforcing steel is not permitted without the approval of the Construction or Bridge Engineer. The welding or tack welding of deformed reinforcing steel is detrimental to the mechanical properties of the bar, unless a special welding procedure with proper preheat and interpass temperature has been established according to the carbon and manganese content of the bar. Any field inspector who discovers welding on deformed reinforcing bars should notify his superiors; or with their permission contact either the Construction or the Bridge Engineer.

When the welding of deformed reinforcing steel is permitted it is part of the specifications or at a location where the stresses of the steel is nil or at a minimum.

SECTION XI

ADDITIONAL INFORMATION AND REFERENCES

Welder Qualification

When a welder is tested for his ability it is conducted by the field Materals Department. These field inspectors issue the test plates and instruction to the welder, witness the welding of the plates and fill out the necessary forms. The machining, testing and reporting is done by Ames Laboratory.

A copy of the instructions to field welders is included in this manual as additional information for the field construction inspector. While these instructions are for the welder they may also be helpful to field welding inspectors.

WELDING METALLURGY

A. Grain size of crystals: several books have been written on the metallurgy of welding, and more is being learned about it every day. Many actions of weld crystals still have not been thoroughly explained. We shall attempt here to give only the basic steps involved in the forming of crystals.

First, we know that crystals are formed when the metal solidifies, and that this solidification may occur suddenly, or may actually occur over a range of temperatures.

Second, the crystalline formed by metals are primarily of three types: (1) Body-centered cubic, (2) face-centered cubic, (3) hexagonal close-packed. The bcc crystals are constructed of nine atoms, the fcc crystals have 14 atoms and hcp crystals have 17 atoms.

Third, when liquid metal solidifies, the crystalline structure forms in two distinct stages, (1) crystal nucleation and (2) crystal growth. The first stage, nucleation, requires that a small amount of free energy be available in the molten metal to assist in the initial formation of a complete crystal unit. The manner in which these atoms come together is still one of the unexplained occurrences of nature. While the nucleation process is endothermic (absorbs heat to proceed), the second stage of crystal growth is exothermic (liberates heat). As solidification by crystal growth proceeds in a pure metal, the evolution of heat arrests any temperature drop. In the case of an alloy, the energy released by the atoms moving into fixed crystalline position occurs over a range of temperature. The upper temperature is called the liquidus, and the lower temperature is called the solidus. Below the solidus the metal consists entirely of solid crystals.

Fourth, the shrinkage of metal upon solidification is a curious action. It is relatively easy to understand that as metal freezes, and the heat of fusion is liberated, the atoms form a more intimate bond and thus a volume decrease occurs. Yet five of the pure metals and a number of their alloys increase in volume upon solidification. This behavior is much the same as water turning to ice. For a given number of atoms the volume in the solid state is larger than in the liquid state.

Fifth, crystals do not stay in a single crystal form, but they grow in the melt and form a pine-tree, dentrite appearance. These growing dentrites meet other growing dentrites and form boundaries and their boundaries determine the grain size. In other words, the grain size and shape in solidified metal is determined by the manner in which the branches from dentrites meet. The presence of grain boundaries has a pronounced effect upon the mechanical properties of metal.

Sixth, the initial grain size of a newly solidified metal generally has an important bearing on any subsequent action; therefore, the need for weldable steels came. With this need came ASTM A-36 steel, our most used, low cost, physically and chemically controlled, weldable steel. Within this steel is produced the crystal grain structure necessary to withstand the heating, melting, resolidification and cooling which is derived from welding. Since it is important to know about crystalline grain structure, it is also equally important to know about its size and what affects its size. The term size being generally defined as fine and coarse for our own use, however, grain size in steel customarily is indicated by ASTM grain size numbers.

Seventh, the grains of a metal may increase in size under a variety of conditions, but the fundamental explanation for their behavior seems to lie in thermodynamics, (the relationship between heat and mechanical energy at work). On heating a metal, larger grains will grow at the expense of smaller ones, thus becoming even larger. In most metals and alloys, a fine grain size improves mechanical properties, particularly toughness and ductility, and so it is not uncommon to apply treatments to refine the grain. Grain refinement is accomplished by heating or annealing the metal to recrystallize a new generation of grains whose size are smaller than the original ones. It may also be done by transformation of the crystal structure within the grains; that is, heating the metal so the crystal lattice grain structure of iron is changed from body-center cubic to face-centered cubic crystals. Some grain refinement may also be obtained by cold-working or hot-working a piece of metal.

B. Stress relieving: stresses in metal build-up when they are cold-worked or welded, and at times even when they are hot-worked. It is, therefore, necessary to relieve these stresses in order to return the metal to its original physical properties. Stress relieving can be accomplished by several different methods. Since we are only interested in the welding end of stress relieving, we shall forget about the others. Preheat is considered a form of stress relieving in that when the initial pass is made the weld metal is frozen at a somewhat slower rate, allowing the grain structure to refine a little more. Since preheat is only used at lower than normal temperatures or on thicker sections it is easy to see that its benefits of stress relieving are small and only useful to a limited extent. A much greater stress relieving is obtained by multiple pass welding, where each successive layer of weld, heats and anneals, the previous layer. Further stress relieving can be obtained by post-heating a welded joint above the re-crystalization point and then slowly cooling the metal. This latter method is known as annealing.

C. Peening: hot or cold peening of weld metal is likened to hot forging or cold rolling of steel. There are many pro and con statements concerning the advisability of using this operation. Peening can be a helpful process but should only be applied when performed in accordance with sound metallurgical judgement. When guided by a good background of metallurgical knowledge, welds may be hot or cold peened to relieve shrinkage stresses and reaction stresses. Welds can be cold peened to increase the yield strength; however, the Highway Commission Field Welding program is set up so a higher yield strength is not desired. Higher yield strength is always accompanied by a loss of toughness and ductility, which is decidedly more harmful than the additional yield strength gained for field use.

The temperature at which a weld is peened is the critical factor. If the weld is peened at a white heat, the weld metal will be too soft and the grain size will not be changed very much. If a weld is peened below a dull red heat, then the metal becomes cold-worked and the ductility is impaired. When peening is done at a dull red heat (slightly above the transition temperature) only then will the grain size be greatly refined. Since weld metal cools rapidly and varies in temperature from start to finish there is only a very small area of weld metal that will be at the correct temperature for peening. In all fairness, we know that multiple pass welds have far greater refinement of grain size than the base metal has in the heat fusion zone. Actually, this is where the refinement is needed, and the only possible refinement here, would be by reheating the metal back above the critical transition temperature and slowly cooling it.

Weld cracking: a good knowledge of welding metallurgy accompanied by good welding procedures for the joints should enable a qualified welder to do a good job of welding without any cracks, regardless of size. As we mentioned earlier, welds are never permitted to have any cracks regardless of the type of inspection.

REFERENCES

The American Welding Society (AWS) has published several books on welding. Following is a list of books that are available from the Materials Laboratory at Ames.

Filler Metal Specifications:

A5.1-69	Mild Steel Covered Arc-Welding Electrodes
A5.5-69	Low Alloy Steel Covered Arc-Welding Electrodes
A5.10-69	Aluminum and Aluminum Alloy Welding Rods and Bare Electrodes
A5.15-69	Welding Rods and Covered Electrodes for Welding Cast Iron
A5.17-69	Bare Mild Steel Electrodes and Fluxes for Submerged - Arc Welding
A5.18-69	Mild Steel Electrodes for Gas Metal - Arc Welding
A5.20-69	Mild Steel Electrodes for Flux-Cored Arc Welding

Welding Handbook
- Section 1 Fundamentals of Welding - 1968
- Section 2 Welding Processes - 1969
- Section 3A Welding Cutting and Related Processes - 1970
- Section 3B Welding Cutting and Related Processes - 1971
- Section 4 Metals and Their Weldability - 1972
- Section 5 Applications of Welding - 1973

Welding Inspection - 1968

Current Welding Processes - 1968

Welding Metallurgy
- Volume 1 - 1965
- Volume 2 - 1967

Resistance Welding - 1966

Brazing Manual - 1963

Soldering Manual - 1964

Electroslag Welding - 1962

APPENDIX A

1. Instruction to Resident Construction and County Engineers, No. 12, Section XXI, Welding Steel Piles.

2. Materials I.M. 560, Qualification Tests for Field Welder.

3. P10A Standard.

IOWA STATE HIGHWAY COMMISSION
Ames, Iowa - October 22, 1974

Instruction to Resident Construction and County Engineers	No. 12, Section XXI
From the Construction Department	Replaces No. 12, Sec. XXI dated January 27, 1974 and Supple. No. 1 to Instr. No. 12, dated November 28, 1972
Subject: Welding Steel Piles	

(NEW) Our specifications provide that all welds conform to the Structural Welding Code AWS D1.1-72 (including Revision 1-73) of the American Welding Society as modified by the American Association of State Highway and Transportation Officials 1974 Standard Specifications for Welding of Structural Steel Highway Bridges. The specifications pertaining to the field welding of steel piles are contained in this instruction.

All welding must be done by a certified welder. When a welder is qualified by the Materials Department, he is issued a certificate showing the types of welds for which he is qualified. The inspector should ask to see the welder's certificate, noting in his records the certificate number, date issued and positions for which qualified. The certificates are good for one year and must be renewed annually except requalification will only be required every two years for field welders who have successfully passed their qualification tests without failure for three consecutive years.

TYPES I AND VI SHELL PILE

Types I and VI shell pile (Union Metal) splices require a fillet weld. The fillet weld should be equal in size to the thickness of the shell wall. The pile extension must be telescoped into the pile to be extended a minimum of 6 inches as shown in Figure A. If bearing has been obtained, the splice shall be welded as shown in Figure C. If more driving is necessary, scallops must be cut in the top 5 1/2 inches of the pile to be extended and the weld made continuous at the contact of the extension and the pile being extended as shown in Figure D.

TYPES II AND VII SHELL PILES

Types II and VII shell piles (such as Armco) are extended with a butt joint requiring a square groove weld with a backing ring used on the inside of the weld connection, as shown in Figure B. The backing ring shall be at least 1 1/2 inches wide and 1/8 inch thick. A band cut off of a pile with a section cut out of the ring makes an acceptable backing ring. The backing ring must make good, continuous contact with the pile at the joint. The space (root opening) between the pile extension and the pile to be extended shall be equal to "T" with a tolerance of plus 1/4 inch and minus 1/16 inch.

TYPE V STEEL H PILES

(NEW) Our Specifications now require that field extensions of steel H piles shall be made only by approved welding procedures involving the use of backing plates. Type V or steel H piles are extended with a butt joint requiring a single-bevel groove weld when welded in the horizontal position (Figure E) and a vee groove weld in the flat position (Figure F). All our steel H piles may be welded as shown in Figures E and F except the 14 X 117 steel H piles. The backing plate must be at least 1/4 inch thick, 1 1/2 inches wide and of the required length to extend full width of web and flanges. If a backing plate thickness of more than 3/8 inch is used, weld the backing plate all around with a fillet weld. A backing plate 1/4 to 3/8 inch thick may be tack welded in place. Backing plates must be bent or ground to fit snug against the flanges and web and the chamfered corners between flanges and web. The required root opening is 1/4 inch with a tolerance of plus 1/4 inch and minus 1/16 inch.

The top of the pile being extended must be cut square with flat ends; the lower end of the extension, both flanges and web, must be beveled to a 45-degree angle (Figure E). The groove angle in the flat position is to be cut to a 45-degree included angle as shown in Figure F. The tolerance of a groove angle joint is plus or minus 5 degrees. The root face of the weld joints in Figures E and F shall be no greater than 1/16 inch. When welding H piles, the web must be welded first.

SURFACE ROUGHNESS

Since most of the weld joints are prepared in the field by freehand oxygen cutting, it requires considerable skill to cut the proper angle and surface of the joint to the smoothness required without grinding. The roughness of oxygen cut surfaces shall not be greater than 1000 as compared to a Surface Roughness Scale. The inspector shall approve the joint preparation before the piles are placed in alignment prior to welding.

PILE ALIGNMENT

Abutting piles to be joined by butt welds shall be carefully aligned. Should the end of the pile to be extended be bent from driving, the bent portion of the pile shall be cut off. In aligning the piles for welding, the webs shall be brought into alignment first. If there is some slight dimensional variation due to fabrication, the pile extension shall be centered so that eccentricity of the flanges is reduced to a minimum.

WELDER CERTIFICATION

Our welders are qualified on 3/8 inch plates. The maximum thickness of plates that may be welded from one side under our normal certification is 3/4 inch. If material thicker than 3/4 inch is to be welded (14-inch 117-pound BP pile), qualification tests on 1 inch plates will be required.

WELDING ELECTRODE AND PREHEAT REQUIREMENTS

The requirements regarding procedures, welding electrodes and preheating temperatures for the various types of steel piling are as follows:

1. Welding must be done with the same process and type of equipment used for qualification.

2. If the operator has qualified on any one of the steels permitted (ASTM A36 and A441), he is qualified to weld on the other, and on SAE 1010 (Type I Pile) or ASTM A 252 (Type II Pile).

3. A welder qualified for manual shielded metal-arc welding with an electrode listed in the following table may weld with any other electrode in the same group designation, and with any electrode listed in a numerically lower group.

Group Designation	Electrode	
F4	EXX16	EXX18
F3	E6010	E6011
F1	EXX28	

The electrodes generally used for manual shielded metal-arc welding are EXX16, EXX18, E6011 and EXX28. For welding steel piles, the first two electrodes above are preferred for reasons shown later.

The meanings of the identifying numbers of the electrodes are as follows:

The XX designation shall be understood to mean the 70 series unless an alloy steel of higher strength is to be welded.

The next digit indicates the position permitted. If the digit is 1, the electrode may be used for welding in any position. If 2 or 3, only the downhand position may be used.

The fourth digit indicates the chemical make-up of the electrode coating. The digit zero indicates a high cellulose sodium; 1, a high cellulose potassium; 6, low hydrogen potassium; and 8, a low hydrogen iron powder. Electrodes 6010 and 6011 are not low hydrogen electrodes. Their use is restricted by preheating requirements.

Preheating of the base metal means that the surfaces of the parts being welded, within 3 inches laterally and in advance of the welding, must be at or above the following prescribed temperature:

1. For A36 steel, Type V, piling, up to and including 3/4 inch thickness, the preheat temperature when other than low hydrogen electrodes are used is 150 degrees F. When welding with low hydrogen electrodes, the preheat temperature requirement is 50 degrees F for a thickness of 3/4 inch, inclusive, and over 3/4 to 1 1/2 inches (BP 14-inch 117-pound) thickness, the preheat temperature requirement is 70 degrees F.

2. For SAE 1010 steel, Type I, piling, the preheat requirement is the same as in No. 1 above.

3. For A252 steel, Type II, piling, the preheat temperature is 225 degrees F when welding with low hydrogen electrodes. Welding with other than low hydrogen electrodes on this steel is not permitted.

Welding when the ambient temperature is below 0 degrees F is not permitted. In inclement or windy weather, suitable shielding must be provided to permit welding in the normal manner.

All electrodes having low hydrogen coverings shall be purchased in hermetically sealed containers or shall be dried for at least two hours between 450 degrees and 500 degrees F before being used. Immediately after drying or removal from hermetically sealed containers, electrodes shall be kept in storage ovens of at least 250 degrees F. Electrodes not used within four hours after removal from the drying or storage oven must be redried before use. For the ordinary field pile welding job, electrodes should be purchased in small packages, allowing for use within the prescribed time limit, unless provision for storage at 250 degrees F is made. The four-hour limit may be increased when humidity is very low, and decreased under humid conditions.

Preference of EXX16 and EXX18 electrodes for field welding may now be apparent. The digit 1 permits welding in all positions. These electrode coatings are low in hydrogen, permitting use on A36 and SAE 1010 steels without preheating the base metal unless the temperature is below 50 degrees F. These electrodes are also required for making the prequalification test.

The restrictions and rules for preheating as outlined above cover the welding of all of our steel piling, since they apply to steel up to one inch thick. If welding is required on thicker plates, other special rules apply. In such case, the Materials Department should be contacted for assistance.

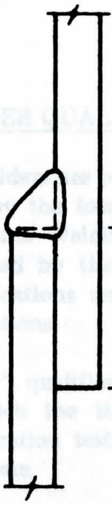


FIGURE A

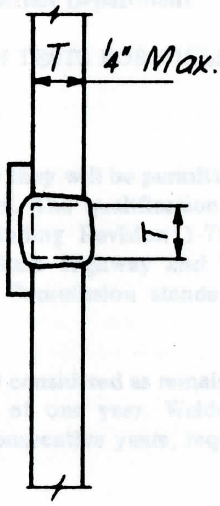


FIGURE B

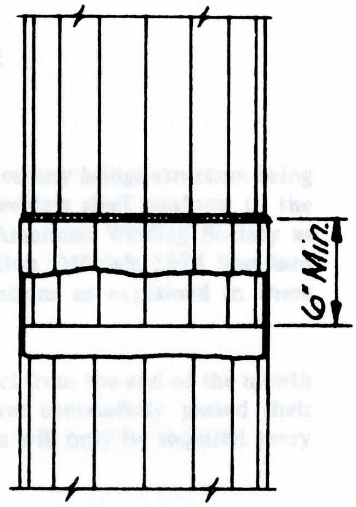


FIGURE C

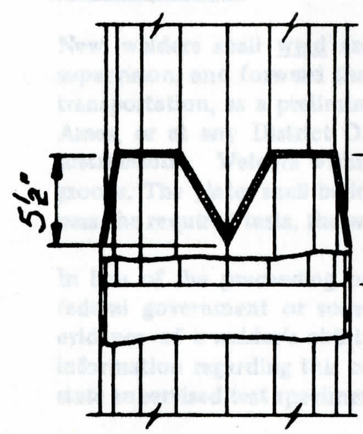


FIGURE D

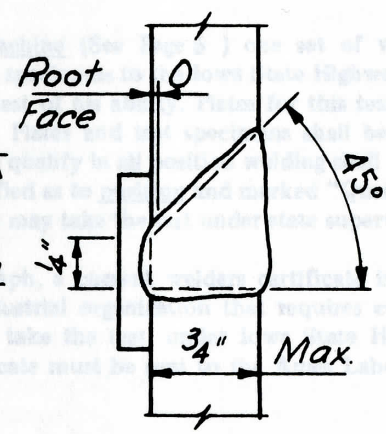


FIGURE E

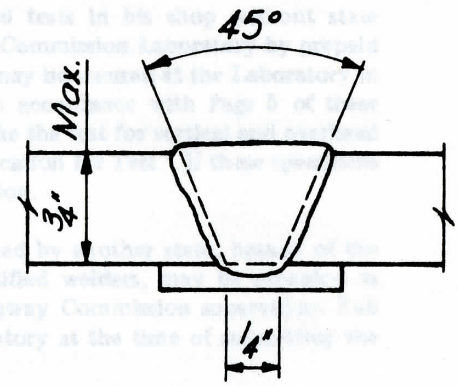


FIGURE F

FIGURE NO	WELDING POSITION	TYPE OF WELD	PILE TYPE P10-A STANDARD	QUALIFIED POSITIONS FOR WELDER
A	Horizontal or Flat	Fillet	I and VI	2F 1F
B	Horizontal or Flat	Square groove	II and VII	2G 1G
C	Horizontal or Flat	Fillet	I and VI	2F 1F
D	Horiz. & Vert. or Flat	Fillet	I and VI	3F 1F
E	Horizontal	Single bevel groove	H Pile with backing plate	2G
F	Flat	Single Vee groove	H Pile with backing plate	1G

IOWA STATE HIGHWAY COMMISSION
Materials Department

QUALIFICATION TESTS FOR FIELD WELDER

WELDER QUALIFICATION

All welders are required to be qualified before they will be permitted to weld on any bridge structure being built by the Iowa State Highway Commission. The qualification of these welders shall conform to the Structural Welding Code AWS D1.1-72 (including Revision 1-73) of the American Welding Society as modified by the American Association of State Highway and Transportation Officials 1974 Standard Specifications and the Iowa State Highway Commission standard specifications as explained in these instructions.

Welder's qualifications herein specified will be considered as remaining in effect from the end of the month in which the test was taken, for a period of one year. Welders who have successfully passed their qualification tests without failure for three consecutive years, requalifications will only be required every two years.

Welder's requalification may be required at any time there is a specific reason to question his ability to make sound welds.

NEW WELDERS

New welders shall weld and machine (See Page 5) one set of weld tests in his shop without state supervision, and forward the test specimens to the Iowa State Highway Commission Laboratory by prepaid transportation, as a preliminary test of his ability. Plates for this test may be secured at the Laboratory in Ames, or at any District Office. Plates and test specimens shall be in accordance with Page 5 of these instructions. Welders wishing to qualify in all position welding shall take the test for vertical and overhead groove. The plates shall be identified as to position and marked "Qualification for Test". If these specimens pass the required tests, the welder may take the test under state supervision.

In lieu of the preceeding paragraph, a current welders certificate issued by another state, branch of the federal government or some industrial organization that requires certified welders, may be accepted as evidence of a welder's ability to take the test, under Iowa State Highway Commission supervision. Full information regarding this certificate must be sent to the Ames Laboratory at the time of submitting the state supervised test specimens.

QUALIFICATION TESTS REQUIRED

The tests described herein are to determine the welder's ability to produce sound welds.

Qualification tests for manual and semi-automatic welders shall be as follows:

1. Qualification Test for Unlimited Thickness.
2. Qualification Test for Limited Thickness.
3. Qualification Test for Fillet Welds Only.

QUALIFICATION TEST FOR UNLIMITED THICKNESS

Joint detail as follows:

1" thick plate, single V groove, 45° included groove angle, ¼" root opening with backing. Minimum length of welding groove shall be 5". Figure 5.18a of AWS D1.1-72

Test Specimens--2 side bend tests.

This test will qualify the welder for groove and fillet welds in material of unlimited thickness for the test position shown in the paragraph entitled -- Position of Test Welds.

QUALIFICATION TEST FOR LIMITED THICKNESS

Joint detail as follows:

3/8" plate, single V groove, 45° included angle, ¼" root opening with backing. Minimum length of welding shall be 5" Figure 5.19a of AWS D1.1-72

Test Specimens -- 1 face and 1 root bend specimen.

This test will qualify the welder for groove welds in material not over 3/4" in thickness, and fillet welds on material of unlimited thickness for the test positions shown in the paragraph entitled -- Position of Test Welds.

QUALIFICATION TEST FOR FILLET WELDS ONLY

Joint detail as follows:

3/8" plate, square butt, 15/16" root opening with backing. Minimum length of welding shall be 5". Figure 5.22.2 of AWS D1.1-72

Test Specimens -- 2 guided root bend specimens.

This test will qualify the welder for fillet welding on material of unlimited thickness for the test positions shown in the paragraph entitled -- Position of Test Welds.

POSITION OF TEST WELDS

Qualification Test		Type of weld and Position of Welding Qualified*	
		Plate & Pipe	
Weld	Plate Position**	Groove	Fillet
Plate-Groove	1G	F	F, H
	2G	F, H	F, H
	3G	F, H, V	F, H, V
	4G	F, OH	F, H, OH
	3G & 4G	All	All
Plate-Fillet	1F		F
	2F		F, H
	3F		F, H, V
	4F		F, H, OH
	3F & 4F		All

* Positions of welding: F=Flat, H=Horizontal, V=Vertical, OH=Overhead

** 1G=Flat groove, 2G=Horizontal groove, 3G=Vertical groove, 4G=Overhead groove; 1F=Flat Fillet, 2F=Horizontal Fillet, 8F=Vertical Fillet, 4F=Overhead Fillet.

REQUALIFYING WELDERS

All qualified welders will require requalification at the end of his current certification. For all position welders, this shall consist of two test welds of the vertical and overhead groove positions. For welders not qualified in all positions, it shall be as outlined in the paragraph entitled -- Position of Test Welds.

FAILURE OF TESTS

The Engineer at his discretion, may allow a retest if evidence is presented showing that the welder, in the past, has exhibited sufficient welding ability. If a retest is allowed the following applies:

A welder failing a weld test is immediately disqualified for those positions represented by the test position in which he failed, and must retest by fabricating two weld test plates of the type on which he failed, both of which must pass.

FAILURE OF RETESTS

The welder's status reverts to that of a new welder for that type of weld (groove or fillet) and, after 6 months he will be required to pass the preliminary tests in all of the positions he failed, before taking the tests under state supervision.

WELDING OF PLATES

In making up test welds, the welder should either restrain the warping of the assembly through the use of clamps to maintain a flat sample, or by pre-setting the plates before welding by bending the back plate (not the tack welds) to approximately 5 degrees to allow for shrinkage caused by welding. Plates shall not be stress relieved or straightened after welding.

When the fillet weld test plates are used, the two fillets are to be made in the test position for which the welder is qualifying. However, the space between the two fillets must also be filled with the same weld metal --- this closing weld may be done in any position. In welding fillets, attention should be given to see that the actual size of both fillets are a full 3/8 in. before the plates are layed down to make the closing welds between the two fillets -- a single pass 3/16 in. fillet is not an adequate test of the welder's ability.

VERTICAL WELDS

All vertical welds for grooves or fillets for field, plant or test plates shall be made with the progression for all passes in the upward direction.

PLATE QUALIFICATION

A. The 3/8 in. standard test plates for groove, butt welds, will qualify a welder for welds in plates up to 3/4 inch thick.

B. Deep Groove Welds - Welders who are to be qualified for groove welds in plates thicker than those outlined in paragraph A, are required to pass a test in plates one inch in thickness. If a test weld is made in the one inch plate, no test weld for that position is required in the 3/8 inch plate. Only those operators who are to be employed for such work should be given this test. Care should be exercised to prevent warping or distortion of the plates during the weld test.

POSITION QUALIFICATION

Welders need only qualify in the position required to do the work on a project, but it is recommended that they become qualified in all positions.

Welders need not take a test in an easy position, such as 1G, when he is tested in a more difficult position, such as 2G or 3G, that automatically qualifies him for the easier position. This is further outlined in the paragraph entitled – Position of Test Welds.

ELECTRODES

Only low-hydrogen electrodes of the F4 group as outlined in A.W.S. will be permitted for the certification of welders for Highway and Railway Bridges. Other electrodes may be used for welder certification on other contracts provided approval is obtained before certification has begun.

The following list of electrodes are approved for use provided the proper minimum preheat and interpass temperatures are maintained as outlined in the paragraph entitled -- Minimum Preheat and Interpass Temperature.

Group	Electrode Classifications	
F4	E-XX16	E-XX18
F3	E-6010	E-6011
F1		E-XX28

The XX designation shall be understood to mean the 70 series unless an alloy steel of higher strength is to be welded.

Suitable ovens must be provided to insure the dryness of all approved low-hudrogen electrodes. Wherever this is not practical, electrodes must be purchased in small packages, and any left over at the end of four hours must be discarded, or redried for at least two hours between 450° and 500° F. Electrodes held in storage after opening a new hermetically sealed package, or after being redried, shall be stored in an oven with a temperature of at least 250° F.

MINIMUM PREHEAT AND INTERPASS TEMPERATURE [1,2].

The minimum preheat and interpass temperature for welding shall be as outlined in the Specifications.

For the benefit of welders, the following table is published:

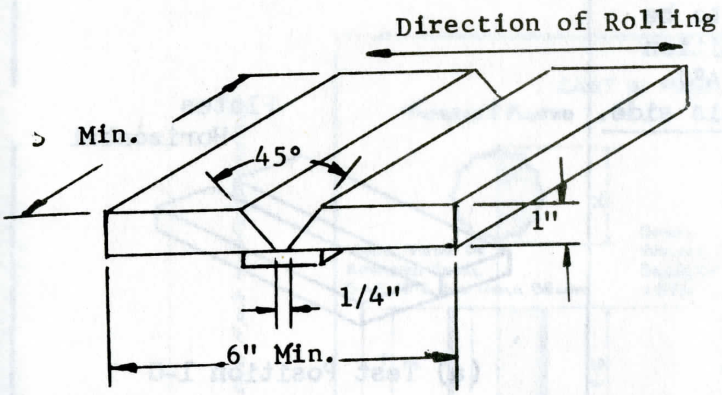
Thickness of Thickest part at Point of Welding	Welding Process: Shielded Metal-Arc Welding with other than Low-Hydrogen Electrode			Shielded Metal-Arc Welding with Low-Hydrogen Electrode			
	A252	SAE-1010	A-36	A252	SAE-1010	A36	A441[3]
To 3/4" Inc.	Not permitted	150° F.	150° F.	225° F,	50° F.	50° F.	50° F.
Over 3/4" to 1½" Inc.		Not permitted	Not permitted	Not permitted	70° F.	70° F.	70° F.
Over 1½" to 2½" Inc.		Not permitted	Not permitted	Not permitted	150° F.	150° F.	150° F.
Over 2½"		Not permitted	Not permitted	Not permitted	225° F.	225° F.	225° F.

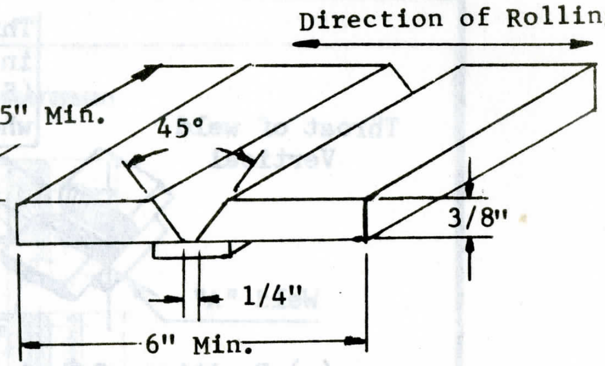
NOTE:

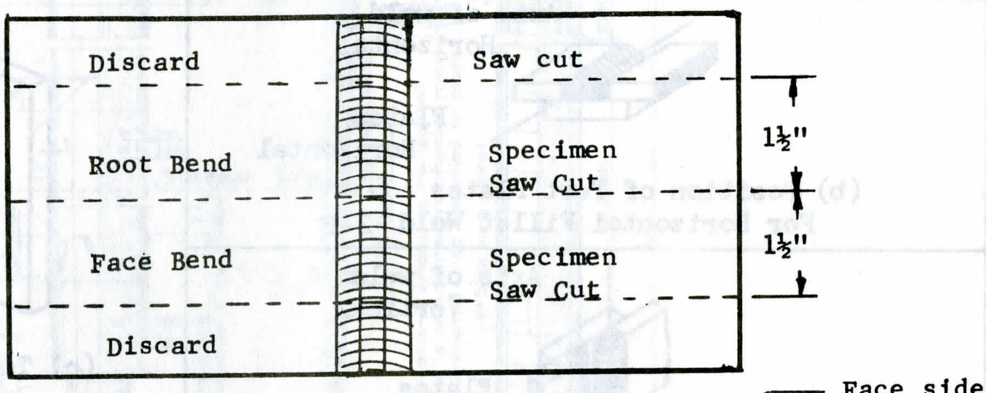
1. Welding shall not be done when the ambient temperature is lower than 0°F.

2. When preheating of the base metal is required, it shall be performed in such a manner that the surface of the parts on which weld metal is being deposited, within 3 inches of the point of welding, both laterally and in advance of the welding, are at or above the temperature specified.

3. Using only E-70XX low-hydrogen electrodes (E-7016, E-7018, E-7028).

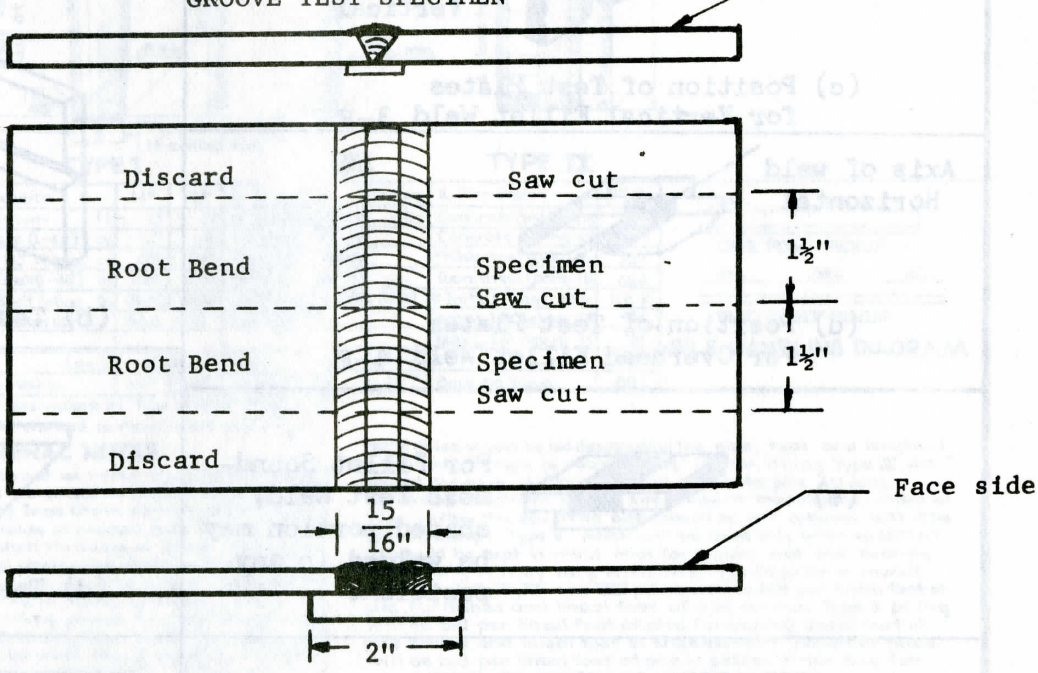






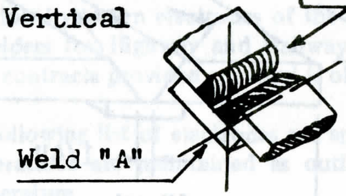
GROOVE TEST SPECIMEN

FILLET TEST SPECIMEN

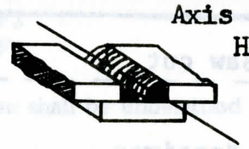


Backing plate and excess weld is to be removed and ground smooth along with cutting two 1-1/2" strips from each plate. This shall be done by the operator for preliminary tests.

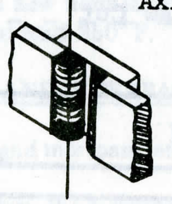
Identification as to type of weld and position shall be stamped or painted on the face side of test specimens. A letter shall also accompany the test specimens giving the operator's name, address, social security number, and a statement that the samples are a "Qualification for Test."



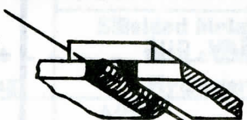
(a) Position of Test Plates For Flat Fillet Weld. 1-F



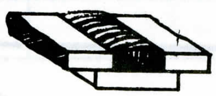
(b) Position of Test Plates For Horizontal Fillet Weld 2-F



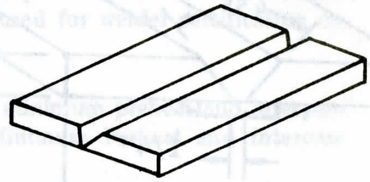
(c) Position of Test Plates for Vertical Fillet Weld 3-F



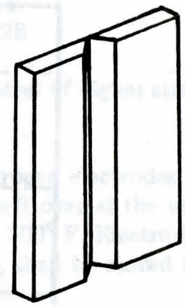
(d) Position of Test Plates For Overhead Fillet Weld 4-F

(e) 

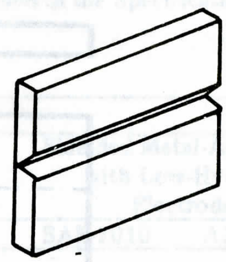
For Fillet Soundness Test Weld, shaded portion may be welded in any position.



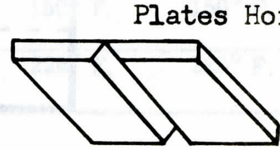
(a) Test Position 1-G



(c) Test Position 3-G



(b) Test Position 2-G



(d) Test Position 4-G

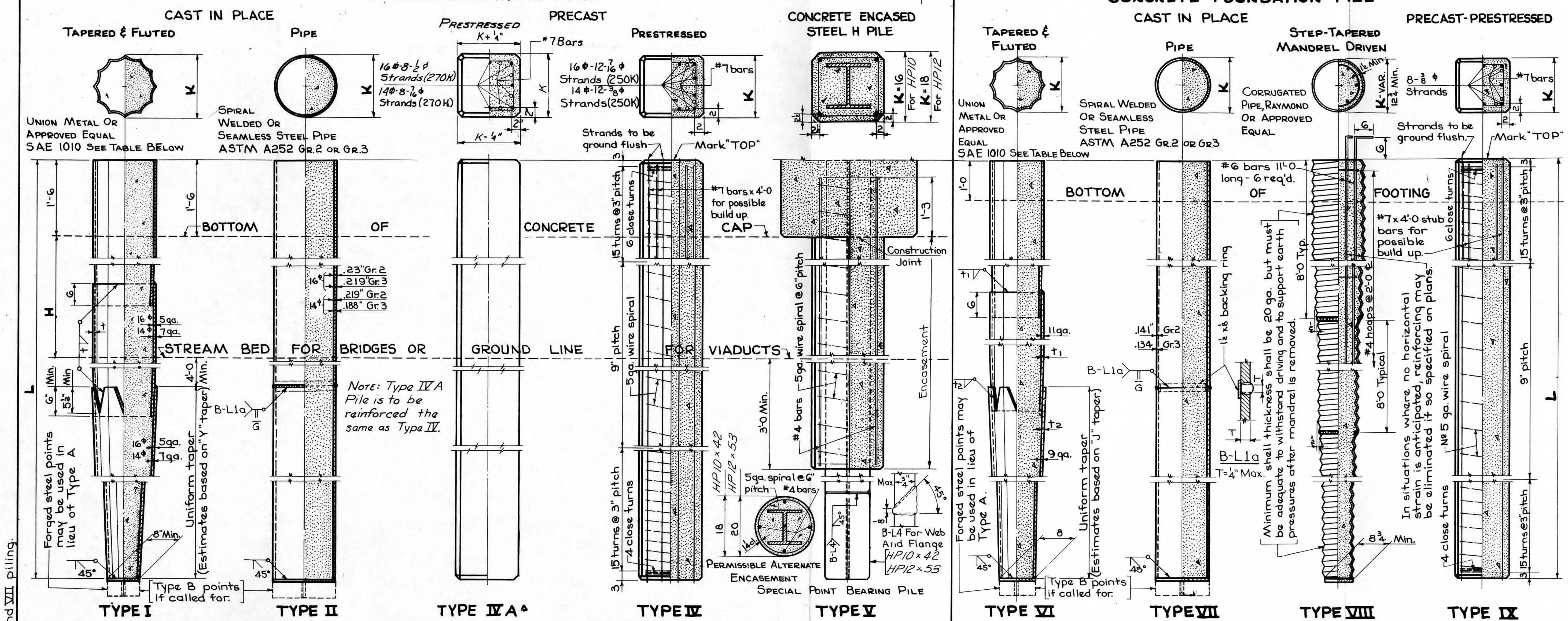
POSITIONS OF TEST PLATES FOR FILLET WELDS

POSITIONS OF TEST PLATES FOR GROOVE WELDS

Revised 6-12-72: Strength of concrete changed on Type I, VI, VII & VIII piles. Class of concrete removed Type I, II, VI, VII & VIII. Encased steel H pile notations changed.
Revised (11-8-71): TYPE III precast reinforced concrete pile deleted. TYPE IV A precast prestressed concrete pile added
Revised (2-5-71): Wall thickness changed, Type II; Welding detail changed, Type V.
Revised (6-4-69): General Notes, other notes and Specifications changed.
Revised (3-4-69): Welding details at field splice point changed for Type II and VII piling.

CONCRETE TRESTLE PILE

CONCRETE FOUNDATION PILE



TYPE I

K Dimension	14⌀	16⌀
H Maximum ft.	13	22
Concrete (L=40') c.y.	1.21	1.46
Concrete 1' change c.y.	.035	.045
*Wt. of Shell (L=40') lb.	1052	1233
Wt. of Shell 1' chng. lb.	26.80	35.40
⊕Specification (Shell)	SAE 1010	
f'c (psi)	3500	
Bearing Value	30T	36T

TYPE II

K Dimension	14⌀	16⌀
H Maximum ft.	13	22
Concrete (L=40') c.y.	1.49 / 1.50	1.95 / 1.96
Concrete 1' change c.y.	.0372 / .0375	.0488 / .0490
*Wt. of Shell (L=40') lb.	1321 / 1200	1594 / 1530
Wt. of Shell 1' chng. lb.	32.20 / 29.17	38.60 / 37.00
Specif. (Shell)	ASTM-A252 Gr.2	Gr.3
f'c (psi)	3500	
Bearing Value	30T	36T

TYPE IV A▲

K Dimension	14⌀	16⌀
H Maximum ft	13	22
Concrete (L=40') c.y.	2.01	2.62
Concrete 1' change c.y.	.050	.066
**Rein. Steel (L=40') lb.	234	274
Rein. Steel 1' change lb.	3.78	4.95
Max. L 1 pt pick-up ft	57	60
Max. L 2 pt pick-up ft	82	86
f'c (psi)	5000	
Bearing Value	33T	38T
⊠Initial Prestress	174K	231K

TYPE IV

K Dimension	14⌀	16⌀
H Maximum ft.	13	22
Concrete (L=40') c.y.	2.01	2.62
Concrete 1' change c.y.	.050	.066
**Rein. Steel (L=40') lb.	237	283
Rein. Steel 1' chng. lb.	3.87	5.17
Max. L 1 pt. pick-up ft.	57	60
Max. L 2 pt. pick-up ft.	82	86
f'c (psi)	5000	
Bearing Value	33T	38T
⊠Initial Prestress	168K	227K

TYPE V

Steel H Pile	HP10x42	HP12x53
K Dimension in.	16⌀	18⌀
H Maximum ft.	16	26
Concrete (H=17) c.y.	1.26	1.58
Concrete 1' chng. c.y.	.063	.079
Rein. Steel (H=17) lb.	75	78
Rein. Steel 1' chng. lb.	3.51	3.65
Specification	ASTM - A36	
f'c (psi)	3500	
Bearing Value Max.	37T	46T

TYPE VI

K Dimension	12⌀
Concrete (L=40') c.y.	.92
Concrete 1' chng. c.y.	.026
*Wt. of Shell (L=40') lb.	677
Wt. of Shell 1' chng. lb.	15.6
⊕Specification	SAE 1010
f'c (psi)	3500
Bearing Value	25T

TYPE VII

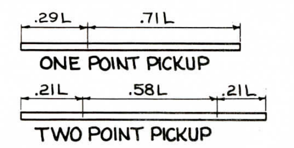
K Dimension	12¾⌀
Concrete (L=40') c.y.	1.26
Concrete 1' chng. c.y.	.0314 / .0315
*Wt. of Shell (L=40') lb.	778 / 784
Wt. of Shell 1' chng. lb.	18.94 / 19.11
Specification	ASTM-A252 Gr.2 / Gr.3
f'c (psi)	3500
Bearing Value	25T

TYPE VIII

K Dimension	Varies
Concrete (L=40') c.y.	.90±
Concrete 1' chng. c.y.	
Wt. Shell & Mandrel lb.	
Reinforcing Steel lb.	121
Specification	SAE 1000
f'c (psi)	3500
Bearing Value	25T

TYPE IX

K Dimension	12⌀
Concrete (L=40') c.y.	1.48
Concrete 1' chng. c.y.	.037
**Rein. Steel (L=40') lb.	182
Rein. Steel 1' chng. lb.	2.64
⊠Initial Prestress	112 K
Max. L 1 pt. pick-up ft.	54
Max. L 2 pt. pick-up ft.	75
f'c (psi)	5000
Bearing Value	28T



PILE HANDLING DIAGRAM

* Includes weight of Type A tip. ** Includes prestressing strands.
⊕ Cold worked to raise yield point to 45,000.
⊠ Increase 5% for artificial curing.

GENERAL NOTES:

Except as noted elsewhere, material, construction, driving and extensions or build ups when necessary shall be in accordance with current Standard Specifications of the Iowa State Highway Commission and current Special Provisions applicable.

Heads of precast piles to be finished smooth and normal to axis of pile.

Shell thicknesses shown are minimum requirements. The method of driving steel shell piles shall be adapted to the type and thickness of shell specified. Any shells which have been improperly driven, broken or are otherwise defective shall be removed and replaced by the Bridge Contractor.

Driving points for cast in place piles shall, unless otherwise noted, be Type A.

Driving points for prestressed piles, if called for, shall be as detailed.

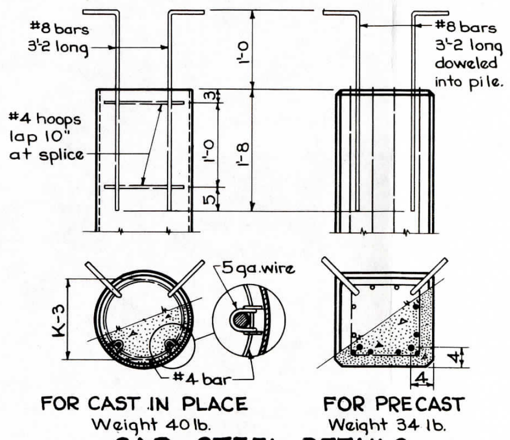
Cap steel will, in general, not be required, but if called for shall be as detailed on this sheet. It should be used for trestle pile if embedment is less than 1'-6. Cap steel shall not be required with Type V piling.

Cost of all driving points and cap steel is to be included in the price bid per lineal foot for piling.

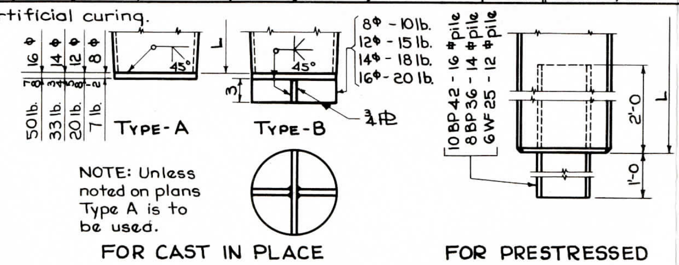
Except as otherwise noted all exposed corners 90° or sharper shall be filleted ¾.

"Bearing value" and "H" as given in tables are recommended design values for ordinary conditions, but may be modified for special conditions on any given job.

Bearing value required shall in all cases be as specified on the plans.



CAP STEEL DETAILS



STEEL DRIVING POINTS
ASTM - A36

NOTE: Piles should be bid designating the size, type and length if a particular type is required; e.g. "14" P10A Piling Type IV, 40'" would mean a 14"⌀ prestressed concrete pile 40' long.

Unless conditions at the site make it inadvisable, choice of type within the specified size should be left optional with the Bidder, except Type V which will be used only when specified. It should be kept in mind that for a given size and bearing value, length may vary with the type (square or round).

Type I, II, VI, VII and VIII piling will be bid per lineal foot of pile furnished and lineal foot of pile driven. Type V piling will be bid per lineal foot of pile furnished, lineal foot of pile driven and lineal foot of encasement. All other piles will be bid per lineal foot of pile in place. Price bid for encasement shall be full payment for necessary excavation and for furnishing and placing all material.

▲Unless otherwise noted, Type IV A piles may be used in place of Type IV piles specified on the plans. The strand (270K) pattern and initial prestress of Type IV A piles may be used for Type IV piles.

Approved by [signature]
Chief Engineer

STANDARD DESIGN
CONCRETE AND STEEL PILES
CAST IN PLACE, PRECAST AND ENCASED
FOR USE IN
PILE BENTS AND FOUNDATIONS
IOWA STATE HIGHWAY COMMISSION
JUNE 1959

P10 A